APPENDIX I

Philips *Aeon* TTY Interoperability Test Report

Testing with the Lober & Walsh *Mobility* and Ultratec *Intele-Modem* TTY Devices

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Version 1.1

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Issue history

Version	Status	Date	Reason
1.0	Initial Release	7 September 1998	Initial document release.
1.1	Final	2 October 1998	Recalculated results using new score program. Now, results are available that calculate both the true character error rate, and the rate including shift errors.

List of contents

List of abbreviations

ACELP	Algebraic Codebook Excited Linear Predictive (a term used to describe the most current digital voice coder used in IS-136 TDMA cellular systems)
AMPS	Advanced Mobile Phone Standard (an EIA/TIA standard defining an analog cellular air interface)
BACTC	Bay Area Cellular Telephone Company, the A-side cellular provider in the San Francisco Bay Area (also known as "Cellular One")
BER	Bit Error Rate
CDMA	Code Division Multiple Access (refers to a digital cellular air interface technology defined in standard EIA/TIA IS-95)
CTIA	Cellular Telecommunications Industry Association
EIA	Electronics Industry Association
FCC	Federal Communications Commission
FSK	Frequency Shift Keying
IS-136	EIA/TIA Interim Standard-136 (a standards document defining a cellular air interface using TDMA technology)
PCC	Philips Consumer Communications
POT	"Plain old Telephone"
RF	Radio Frequency
RSSI	Received Signal Strength Indication
SP	System Provider
TDMA	Time Division Multiple Access (refers to a digital cellular air interface technology defined in standard EIA/TIA IS-136)
TIA	Telecommunications Industry Association
TTD	Text Telephone Devices
TTY	Teletype

List of references

[1] TTY Test Procedure, Cellular Telecommunications Industry Association, Joint Task Force, Working Group 1/3, 12 February, 1998

[2] Philips *Aeon* TTY Interoperability Test Report -- Testing with the Lober & Walsh *Mobility* TTY Device, Jim DeLoach, Version 0.01, 23 June, 1998

1.

1. Introduction

Philips Consumer Communications (PCC) has conducted a series of live-network tests using the Philips *Aeon* TDMA digital cellular telephone with the Lober & Walsh *Mobility* and Ultratec *Intele-Modem* TTY devices, in our ongoing effort to characterize TTY performance over realistic IS-136 digital cellular channels [2]. Goals of this test were to explore:

- how well different TTY devices interoperate in a cellular environment,
- how TTY performance changes when characters are sent at "full rate" (sent continuously one after another) vs. "half rate" (gaps present between characters, as might be the case with a typical-speed typist),
- how TTY performance differs on digital TDMA channels verses analog, all other factors being equal, in order to baseline performance.

The *Mobility* and *Intele-Modem* were selected because each can be directly connected to a computer to capture the received text, enabling automated results scoring. Automatic scoring is indispensable since manual scoring is (1) excessively time consuming, and (2) prone to errors. Additionally, the designers of these two devices, Lober & Walsh Engineering and Ultratec, have both been very helpful and willing to work with us to overcome problems encountered.

Live calls were made using the Bay Area Cellular Telephone Company (BACTC) Network (a.k.a. "Cellular One") in the San Francisco Bay Area, from an average signal strength fixed location. Our results are shown in the following sections. Test methodology is described in section 2, results in section 3, and conclusions in section 4.

2. Test Methodology

2.1 Test Strategy

This test campaign was designed to explore the following operational scenarios:

- TTY device type and position:
  - *Mobility* (land) / *Mobility* (cellular)
  - *Intele-Modem* (land) / *Mobility* (cellular)
  - *Mobility* (land) / *Intele-Modem* (cellular)
  - *Intele-Modem* (land) / *Intele-Modem* (cellular)
- direction of communication:
  - forward (from the land to the cellular)
  - reverse (from the cellular to the land)
- transmission rate:
  - full rate (simulating a fast typer or an automated system)
  - half rate (simulating a slower typer)
- cellular voice channel type:
  - digital TDMA (IS-136) ACELP vocoder voice channel
  - analog AMPS voice channel

Each possible combination of these four operational scenarios was tested, and thus 32 test permutations performed. Data collects were taken at a moderate signal strength, fixed, location (the author's home in Sunnyvale, California), using the live, Bay Area Cellular Telephone Company (BACTC) IS-136 TDMA network. This location was chosen because it has produced the most reproducible results in the past, and is typical of the well engineered BACTC network. A description of the cellular conditions observed during testing at this location is shown in section 3.1.

2.2 Test Set-up

Audio levels to and from the Aeon cellular phone were matched to each TTY device, with the help of engineers from both TTY manufacturers. However, neither we nor the TTY manufacturers are sure that the levels selected were optimal. Considerable questions remain on the relationship between the signals at the cell phone interface and the signals at the landline, in various networks and in various conditions (i.e. TDMA vs. CDMA vs. analog calls). Indeed, our results (discussed below) suggest that there is an inconsistency between the levels preferred by each manufacturer, and matching that works between two like TTY devices does not work with two differing TTY devices. *PCC recommends that the TTY Forum focus on audio level standardization at the TTY/cellular phone interface.*

The *Intele-Modem* is designed for a landline telephone connection only. Therefor, modifications were required within the unit to bypass the phone interface circuitry and separate the receive and transmit audio. Level conversion was also added. A design for these modifications was provided by Ultratec.

Figures 2.2-1 and 2.2-2 show the test setup in the reverse and forward directions, respectively. In all cases, one TTY device is using the Aeon cellular phone while the other is using a standard landline phone connection.

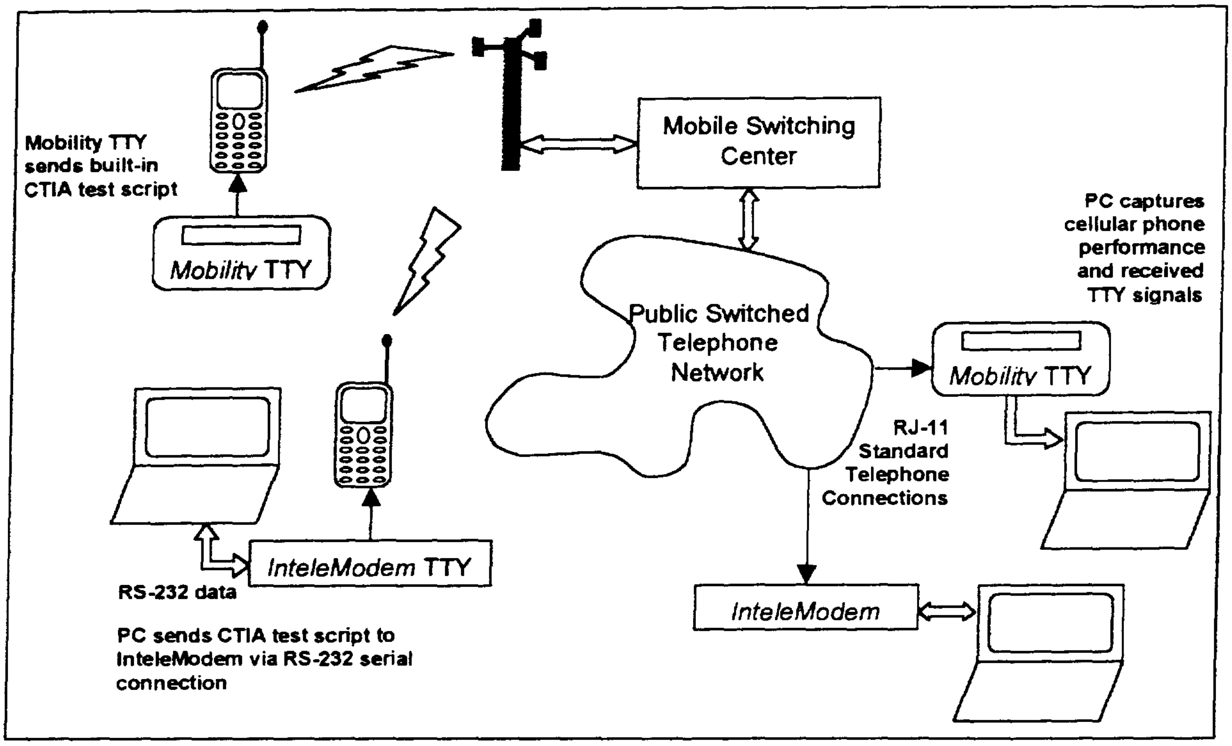

Figure 2.2-1 Test Setup – Reverse Audio Path

An audio path is established – using either a digital or analog voice channel – and the sending TTY transmits 45.45 baud baudot TTY characters per the CTIA published test script shown in Appendix A. The *Mobility* TTY unit can be put into a test mode whereby it transmits the CTIA script automatically. The *Intele-Modem* must be connected to a PC, and the test script sent to it using a terminal emulation program. The original CTIA script was used since when these data collects began, the *Mobility* TTY units in our possession only supported the old script. Also, the old script is preferable since it contains a portion of plain text which allows the tester to recognize failures.

The receiving TTY receives the data and transmits it to a lap-top PC using an RS-232 serial data connection. A PC connected to the receive TTY unit captures the received text using the *HyperTerminal* program. The Aeon phone's own antenna was used and was extended.

Each possible combination of these four operational scenarios discussed in section 2.1 were set up, and data captured. "Half rate" transmission can be selected in the *Mobility*'s test mode. To send half rate on the *Intele-Modem*, PCC wrote a special terminal emulation program that sends characters from the PC to the *Intele-Modem* at a user-selectable rate. There is an important difference between how the *Mobility* and *Intele-Modem* send "half rate": the *Mobility* keeps the "space" tone active during the pause, while the *Intele-Modem* removes both tones during the pause.

Received text files were assessed using the "score" program provided by Lober & Walsh. This program is fed a file with the known true text (shown in Appendix A), and the received text file. It correlates the two files and determines the error rate, as well as the number of characters: sent, correctly received, added, missing, and changed. The error rate equals the number missing or changed divided by the total number. The score program considers *all* characters corrupted by letters/figures shift problems to be errors.

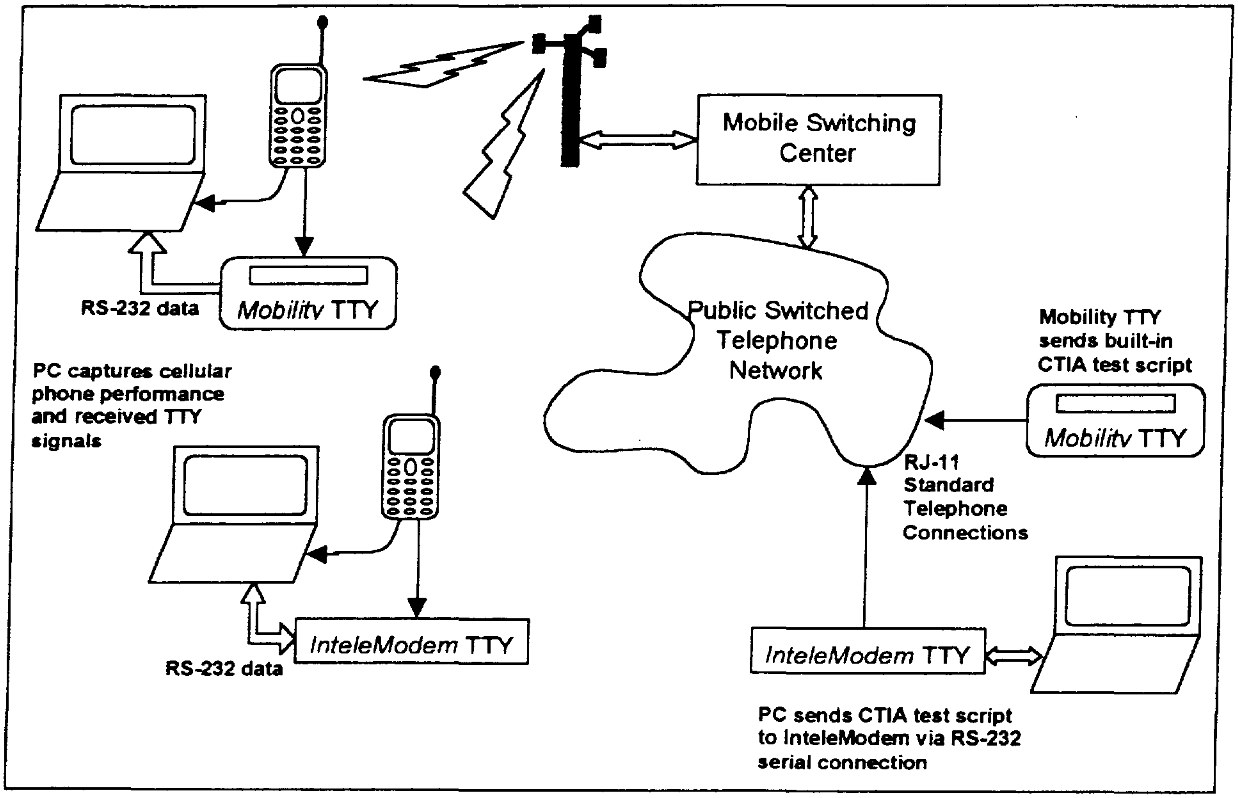

Figure 2.2-2 Test Setup – Forward Audio Path

A problem was discovered in the interpretation and scoring of carriage returns and line feeds. Different TTY devices seem to add these characters by themselves or translate them in various ways. To ensure consistent and fair results, Lober & Walsh created a version of the "score" program (time date stamp "8bc32521", 66667 bytes, signature "00004550") that ignores all carriage returns and line feeds, which we used to generate the results shown in this report.

A second version of the score program (time date stamp "8325252b", 69675 bytes, signature "00004550") has been created to calculate "character error rate" in two ways:

- Include errors that propagate after a shift error (this is the original method). Lober & Walsh refer to this as the "Text Match" method.

- Do not include errors that propagate after a shift error.). Lober & Walsh refer to this as the "Baudot Match" method. This method yields a "pure" character error rate whereby all character errors are given equal weight. This method produces results that are inherently less noisy, but do not reflect the reality of Baudot -- which is that letters/figures shift errors are a real problem.

Results using both calculation methods are shown below.

A proprietary PCC program is used to configure the Aeon phone (for example to force it to use either a digital or analog voice channel), and to capture performance information such as Received Signal Strength Indication (RSSI), Bit Error Rate (BER), and channel number to a file during test calls. Later, these files are processed to characterize cellular performance.

2.3 Required Equipment

Table 2.3-1 lists the required equipment.

Quantity	Equipment
1	*Aeon* IS-136 Cellular Telephone, with valid subscription on an IS-136 capable network
1	Aeon interface cable (includes audio in, audio out, and data)
2	Lober & Walsh *Mobility* TTY device
2	Ultratec *Intele-Modem* TTY device (one unit specially modified to facilitate audio connection to a cellular phone, per instructions provided by Ultratec)
1	Custom interface cable for interconnecting Aeon interface cable audio in and out (BNC connectors) with the *Mobility* TTY RJ-45 jack.
1	Custom interface cable for interconnecting Aeon interface cable audio in and out (BNC connectors) with the *Intele-Modem*.
1	Standard POTs phone line
2	Lap-top PCs (one with a PCMCIA serial adaptor for a 2nd serial port)
	Custom terminal emulation software for sending "half rate", available from PCC
	Score.exe program, available from Lober & Walsh
	CTIA published test script file (text shown in Appendix A)

Table 2.3-1 Required Equipment

3. Test Results

Table 3.1 and Table 3.2 show results matrices, organized by operational scenario. Table 3.1 results include shift errors, while Table 3.2 results do not, and thus reflect the true character error rate.

		Land: *Mobility* Cell: *Mobility*		Land: *Intele-Modem* Cell: *Mobility*		Land: *Mobility* Cell: *Intele-Modem*		Land: *Intele-Modem* Cell: *Intele-Modem*	
		forward	reverse	forward	reverse	forward	reverse	forward	reverse
		M (land) ↓ M (cell)	**M (cell) ↓ M (land)**	**I (land) ↓ M (cell)**	**M (cell) ↓ I (land)**	**M (land) ↓ I (cell)**	**I (cell) ↓ M (land)**	**I (land) ↓ I (cell)**	**I (cell) ↓ I (land)**
digital	full rate	7 1.1%	10/17 5.6%	15 12.0%	35 0.7%	1 1.6%	21 24.4%	26 3.0%	23 0.7%
digital	half rate	8 0.5%	9 2.4%	16 27.3%	36 0.7%	2 0.7%	22 6.1%	25 2.2%	24 5.8%
analog	full rate	5 2.0%	11 0.0%	13 0.3%	33 0.3%	3/18 2.2%	19 6.4%	27 0.6%	29/31 0.7%
analog	half rate	6 2.4%	12 0.0%	14 1.4%	34 0.2%	4 1.2%	20 9.0%	28 0.3%	30/32 0.4%

Table 3-1 Results Matrix -- *Including Shift Errors*

		Land: *Mobility* Cell: *Mobility*		Land: *Intele-Modem* Cell: *Mobility*		Land: *Mobility* Cell: *Intele-Modem*		Land: *Intele-Modem* Cell: *Intele-Modem*	
		forward	reverse	forward	reverse	forward	reverse	forward	reverse
		M (land) ↓ M (cell)	**M (cell) ↓ M (land)**	**I (land) ↓ M (cell)**	**M (cell) ↓ I (land)**	**M (land) ↓ I (cell)**	**I (cell) ↓ M (land)**	**I (land) ↓ I (cell)**	**I (cell) ↓ I (land)**
digital	full rate	7 0.5%	10/17 2.6%	15 6.6%	35 0.5%	1 1.2%	21 13.9%	26 1.5%	23 0.5%
digital	half rate	8 0.2%	9 1.3%	16 16.4%	36 0.5%	2 0.6%	22 2.6%	25 1.3%	24 2.8%
analog	full rate	5 0.9%	11 0.0%	13 0.3%	33 0.2%	3/18 1.3%	19 5.1%	27 0.4%	29/31 0.5%
analog	half rate	6 1.2%	12 0.0%	14 0.9%	34 0.1%	4 0.6%	20 3.1%	28 0.2%	30/32 0.2%

Table 3-2 Results Matrix -- *NOT Including Shift Errors (true character error rate)*

The column indicates "TTY device type and position" and "direction of communication". The row indicates "cellular voice channel type" and "transmission rate". Each matrix element shows the data collect number in blue, and the average *character error rate* for all data collected of that permutation. Complete results are shown in Appendix B.

In general, performance is relatively good -- averaging 2 or 3 per cent on digital channels -- when two similar TTY devices are communicating with each other (a *Mobility* with a *Mobility*, or an *Intele-Modem* with an *Intele-Modem*). However, when an *Intele-Modem* sends to a *Mobility*, performance falls off sharply. Lober & Walsh engineers believe this is due to audio level inconsistencies between the two devices, although this is unconfirmed. Curiously, performance results when a *Mobility* sends to an *Intele-Modem* are some of the best seen.

As expected, analog voice channel performance is generally better then digital voice channel performance. There is no discernible difference between "half rate" and "full rate" on analog voice channels. However on digital channels, "half rate" seems to improve performance when the *Mobility* is sending -- probably due to the way the *Mobility* maintains the "space" tone during pauses.

Shift errors clearly play a big part in TTY errors. Nearly every collect taken shows much worse results when shift errors are included. This is particularly true when a TDMA digital channel is used.

Several data collects were repeated when the data seemed anomalous. Often, the results diverged even though all factors under the tester's control were identical. For example, collect numbers 10 and 17 were taken in identical conditions (the phone wasn't even moved!), yet collect 17 scored 3.7 per cent and collect 10 scored 7.5 per cent -- over double the character error rate. No difference was seen in the cell phone's received signal strength or bit error rate for these collects, suggesting factors such as cellular system load were not an issue. Clearly, field data is just "noisy".

Time was not available to perform the volume of testing necessary to average out the "noise" inherent with field data. Too many results-influencing factors are unknown to, and beyond the control of, the field tester. Thus, field testing is a great way to get a feel for typical performance, and is the ultimate reality check, but it is not the way to obtain reproducible, consistent results!

3.1 Cellular Conditions During Testing

Table 3.1-1 shows the received signal strength distribution observed during all testing. Signal strengths were typically in the -75 to -80 dBm range when using digital traffic channels, and -75 to -85 dBm when using analog voice channels -- typical values for the well engineered BACTC network. Digital traffic channel bit error rates were 0.01 per cent or less, over 99 per cent of the time.

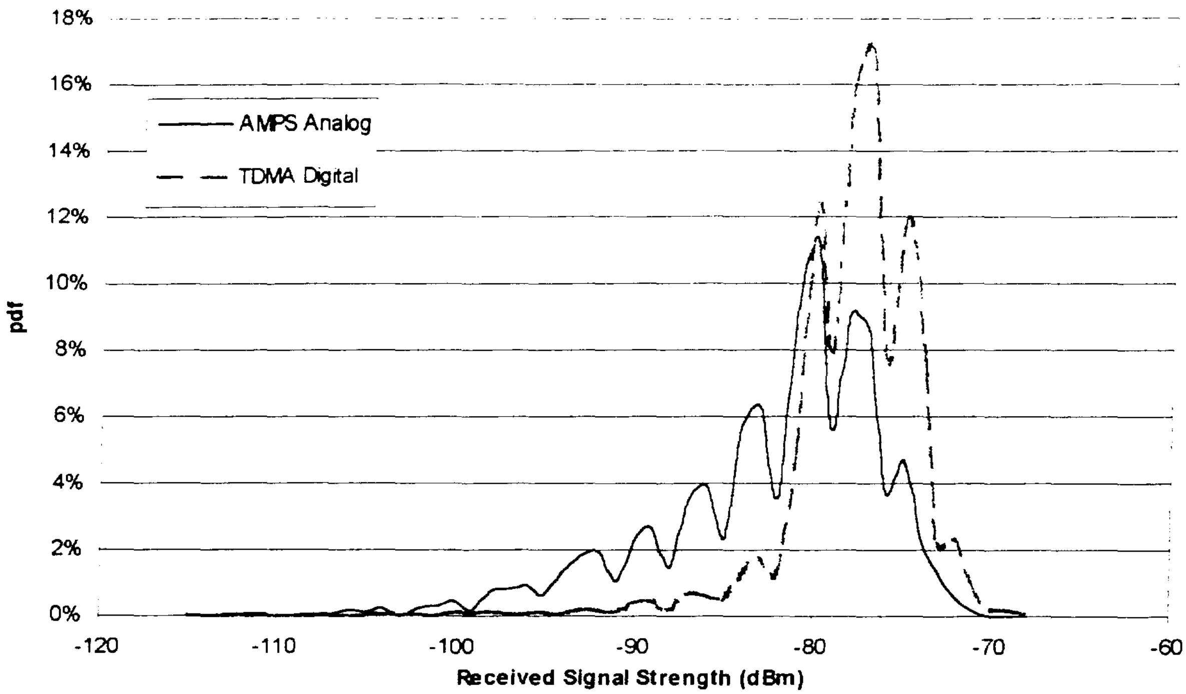

Figure 3.1-1 Distribution of Received Signal Strength for Digital and Analog Channels

3.2 Failure Modes

Three perceptible failure modes were noticed when analyzing results:

- isolated character errors
- letters/figures shift error blocks
- character alignment error blocks

The actual cause of individual character errors was not determined in this testing. However, what is clear is that these single errors trigger shift error blocks and character alignment error blocks, which then cause the majority of character errors.

When either a "letters" or "figures" shift character is corrupted, all subsequent characters are displayed in the wrong mode until the next shift character is correctly received, causing a "block" of errors. This failure mode, inherent to Baudot code, was observed frequently during testing. Appendix B lists each such occurrence, and gives the approximate size of each block.

Character alignment errors occur when the demodulator looses its reference to the beginning of a character. This is most typically observed when a sequence of repeated characters is transmitted -- such as the dashes in the CTIA script -- where a block of errors will propagate. While this failure mode is more likely to be recognized for a sequence of repeated characters, it undoubtedly occurs at other times as well, it is just less recognizable and may only affect smaller blocks. The character alignment method used in TTY transmission comes from the wired serial communications world, and is inherently weak as a method of acquiring and maintaining character alignment in a high error rate, radio environment.

No character alignment errors were observed when the *Mobility* was sending at "half rate" -- probably since the *Mobility* transmits the "space" tone during the pauses, which helps the receiving demodulator reacquire character alignment. The *Intele-Modem* had no such benefit.

4. Conclusions

Testing was performed using the Philips *Aeon* IS-136, TDMA digital cellular telephone with the Lober & Walsh *Mobility* and Ultratec *Intele-Modem* TTY devices in a typical, *stationary* location. Goals of this test were to determine how well different TTY devices interoperate in a cellular environment, determine if sending characters at a slower rate ("half rate") performs differently then at "full rate", and baseline digital performance against analog performance. Conclusions are as follows:

- *When communicating between like TTY devices*, on digital TDMA channels, character error rates averaged about **2 to 3 per cent**. Performance over analog channels averaged about **1 per cent**. Both TTY devices performed equally well.
- Performance degraded sharply when communicating from an *Intele-Modem* to a *Mobility*. Interestingly, when communicating from a *Mobility* to an *Intele-Modem*, performance was good. Inconsistent audio level requirements between the TTY devices may be causing these increased errors. ***PCC recommends that the TTY Forum focus on audio level standardisation at the TTY/cellular phone interface.***
- Sending characters at a slower rate ("half rate") seemed to improve performance slightly when the "space" tone was maintained during the pauses. Maintaining the "space" tone may be reducing the number of character alignment errors.
- The blocks of incorrectly interpreted characters that result from isolated Shift errors play a big part in high TTY character errors rates, particularly on digital channels. Replacing Baudot with a modern character set would improvement performance significantly.
- Field testing is a great way to get a feel for real-life conditions, and is the ultimate reality check, but field data is "noisy"! Field conditions do not allow the control needed to produce consistent, repeatable data, and thus care must be taken how field data is used.
- For testing requiring consistent, repeatable results, lab testing is needed. PCC recommends that these TTY testing techniques be adapted for use at high quality cellular labs. Such labs exist at the facilities of handset and infrastructure manufacturers, some cellular system operators, and at CTIA's certification facility in Lexington Kentucky.

PCC sincerely thanks Joshua Lober of Lober & Walsh Engineering and Ron Schultz of Ultratec for their help during these tests.

Appendix A – CTIA published test script

```
THE FOLLOWING FILE IS FOR TESTING TTY ERROR RATES.
THE NEXT 28 LINES ARE RANDOMLY GENERATED CHARACTERS:
"!"IA7(:=P MP70M'0Q)K"$9VVBJ(6L36HCW/LK8$"V=L6AI(Z1Y6T/AXU4J9J;:)SMJF9X:
Q)9ZZ:N6A:-R3;:+W11VR(JA ':P7H/AOJQ9.WI( 38 W2'513UHO/;WBC 9K7-RFW)Q/62?
?R549I4EO9"LVIRS H-3VTWE90L7G3D,68W=EHZP:P7 ==0P;87(B:!5Z0W(ORX!I?,/ 8"R
(GD"J-BMLJSA Q7=BH9!MD"KUZ$M!!IX;DOU8B?.F CBDILR +K4O4()ONO.EP!XY6258G,7
3=CGOR3?.Y/VKMSP8787QYB=8,E'G9UA'I!?6;0L ORT!!7GU:3)?:22/:0CQNP3D$0W4Y1W
09B=CXP$-$:M1RKBK+BF1/+. YO(:LT6M 5NS6LH R.28 RK?S?VHS6QD:FC+F1GY)UEY-X,
9A0(K),E4)O'BZD:/SG2.5XVL:G2K:9'("YN1QI20OCIVVYC.BSU7C8Y3BP)$LLD".2RJONJ
;.3)M;+P1=9?X(FJTN?FLHJ 2FT"7J.,JNBZR AG$B!061+XDN 2QYWDESO2AY8Y.-:36)8J
4QHK5:4T7HSW! $2F5YV9PO8XD- 6187TZ'BMX;U5/)Z(,FE/MJ-L0RR"K-$.7IN?$R8+I!.
K,$NXG;3I (!8OX,JMG;Q39 ?J!/R.CBD$9YK :XYUN.WIN(I.G/$ D,="Y T$6;; 4ZB$UF
BD)L3YL/19?7ION9GUUBGPJXIH-;C!57R (ZT1+.,4SD/QZ:7+0X$QV,VTOIL8GC$H79" !P
(F=4GYI;B ,OHO3+D956 +=A=SB+A/;L4PZC7C!T3D:WMF'L BK62/2I0V6NVI-9$ GRW(U4
;2'RSP77$A.9M(07+N;N=,I VR."OV+!I+  MDJN= 462H??SEI/+8'B'(R'!D="'2WX'.PR
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 E9 KF'ZWILK1ECDP)4W 3MYA8!B!W7R';BVY/?K  T""/.4KHO)1P F"R$WM7D.331U,IG-
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9ZN(;W(RH/ 6KVAWUKQ3S;KLH-VFUMK+:8)8A,H+T.440!PEF/"8.TW"F VZ73$IRL295JNK
,SVMSL?NG1)LQ6Y"YNM1Z,S+26,D+;XI!-=K/YG" SRP0W"+'E581$4WA 1G2)6FEL4Y$O S
?$;(7-/24=U9HIOT9/'SH:TOKB45IPI2J"IHS.GE, !D 62!.=7!/VQJT".HO//UH(41.7!=
MU4UCW/QNL3AP+RSHW'LHK'J='"PQZZ?P$R09!DX+;I !O!$ULN60Z0W9DXVL!A05$RCKX 8
W5+"Z7)Q W'R+E06YFV;;)8 ,$XAZ-EWO 8P)-G+X/4MXF.0N6+40UHW5E7P8E7E34MQ5A.I
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RHPWIYR,4OZL!8L=H"UJU$X="0":2E,W L5EC F30Y$38C;FS,7?X1RJE)'S8BO5L/ZR8T4M
7HNHD'=DKSC'7/ A2;F7G !BBCL2P(7NQXCPVN6.ZWR,O6L=:M2-M=4?HB)M"3LD)$6VY(9O
-);A27J$608416Y?34GF+F,?(T4R"KB$F!;2?4S6?2L.,C"K4W4P/(2HZ AMUZSPZ-W3'QR=
 L7ZL! W6O3/"UGT-JNH?!S B/))HB6ANYUR?/X;:269D1FFAN9K;!?'P$4BE$,WOOL7/MIE
?$ONDK:I7?0 P3!R!V)"(7O$FH$:L O..SJ."7OFR M" (:36Q=OL1PL:XD)L/6A.O  =TTG
```

NOW STARTS SEVERAL LINES OF PLAIN TEXT TEST EXAMPLE EMERGENCY MESSAGES:

A TYPICAL POLICE-TYPE CALL

911: POLICE AND FIRE

CALLER: I NEED THE POLICE SENT RIGHT AWAY

911: OK, FIRST OF ALL, WHAT IS YOUR ADDRESS?

CALLER: 7101 YATES AVENUE NORTH, BROOKLYN PARK

911: OK, 7101 YATES AVENUE, WHAT'S GOING ON THERE?

CALLER: I THINK I HEAR SOMEONE IN MY BASEMENT

911: IF YOU CAN LOCK YOURSELF IN A BEDROOM, DO SO NOW. I'M GOING TO DISPATCH THE POLICE NOW, SO STAY ON THE PHONE WITH ME AND DO NOT HANG UP

CALLER: OK

911: POLICE ARE ON THE WAY, ARE YOU HEARING ANY NOISES NOW? DO YOU HAVE ANY FAMILY MEMBERS THAT MAY BE DOWN THERE?

CALLER: I'M NOT HEARING ANYTHING NOW.. AND NO, I LIVE ALONE.

911: OK, I'M GOING TO KEEP YOU ON THE PHONE WITH ME UNTIL THE POLICE ARRIVE

A TYPICAL EMS-TYPE CALL

911: POLICE AND FIRE

CALLER: I NEED AN AMBULANCE SENT RIGHT AWAY FOR MY HUSBAND

911: OK, WHAT IS YOUR ADDRESS?

CALLER: 6825 HUMBOLDT AVENUE, CHAMPLIN

911: OK, 6825 HUMBOLDT AVENUE, CHAMPLIN, WHAT IS WRONG WITH YOUR HUSBAND?

CALLER: HE IS HAVING CHEST PAINS

911: DOES HE HAVE A HISTORY OF HEART PROBLEMS?

CALLER: NO

911: OK, HAVE HIM SIT DOWN, KEEP HIM CALM. TURN YOUR OUTSIDE LIGHT ON SO WE CAN SPOT YOUR HOUSE FASTER. I AM SENDING AN AMBULANCE AND POLICE.

A TYPICAL FIRE-TYPE CALL

911: POLICE AND FIRE

CALLER: I WANT TO REPORT A FIRE

911: WHAT IS YOUR ADDRESS?

CALLER: 1901 DUPONT AVENUE, PLYMOUTH

911: OK, 1901 DUPONT AVENUE, PLYMOUTH. WHAT IS ON FIRE?

CALLER: MY GARAGE

911: IS THE GARAGE ATTACHED TO THE HOUSE?

CALLER: YES

911: OK, I NEED YOU TO HAVE EVERYONE GET OUT OF THE HOUSE AND GO ACROSS THE STREET AND WAIT FOR FIRE AND POLICE TO ARRIVE.

END OF TEST SCRIPT

Appendix B – Test Data

No.	Date	Source TTY Device	Source Phone	Destination TTY Device	Dest. Phone	Analog/ Digital	Full / Half	Error Description	Error Rate (Text Match)	Error Rate (Baudot Match)
1	7/29/98	*Mobility*	land	*Intele-Modem*	Aeon	digital	Full	scattered errors	1.55%	1.16%
2	7/29/98	*Mobility*	land	*Intele-Modem*	Aeon	digital	Half	scattered errors	0.74%	0.56%
3	7/29/98	*Mobility*	land	*Intele-Modem*	Aeon	analog	Full	one large char alignment error propagation block, several L/F blocks	4.24%	2.54%
4	7/29/98	*Mobility*	land	*Intele-Modem*	Aeon	analog	Half	scattered errors. one medium L/F block	1.18%	0.60%
5	7/29/98	*Mobility*	land	*Mobility*	Aeon	analog	Full	scattered errors. two medium L/F blocks	1.97%	0.93%
6	7/29/98	*Mobility*	land	*Mobility*	Aeon	analog	Half	scattered errors. two medium and one small L/F blocks	2.39%	1.23%
7	7/29/98	*Mobility*	land	*Mobility*	Aeon	digital	Full	scattered errors. one medium L/F block	1.13%	0.48%
8	7/29/98	*Mobility*	land	*Mobility*	Aeon	digital	Half	scattered errors. one small L/F block	0.54%	0.15%
9	7/30/98	*Mobility*	Aeon	*Mobility*	land	digital	Half	scattered errors. one small L/F block	2.42%	1.34%
10	7/30/98	*Mobility*	Aeon	*Mobility*	land	digital	Full	one large char alignment error propagation block, several L/F blocks. scattered errors	7.54%	3.46%
11	7/30/98	*Mobility*	Aeon	*Mobility*	land	analog	Full	no errors!	0.00%	0.00%
12	7/30/98	*Mobility*	Aeon	*Mobility*	land	analog	Half	no errors!	0.00%	0.00%
13	7/30/98	*Intele-Modem*	land	*Mobility*	Aeon	analog	Full	small, isolated errors.	0.32%	0.25%
14	7/30/98	*Intele-Modem*	land	*Mobility*	Aeon	analog	Half	scattered errors. one small L/F block	1.43%	0.93%
15	7/30/98	*Intele-Modem*	land	*Mobility*	Aeon	digital	Full	scattered errors plus two large and one small L/F blocks	12.03%	6.62%
16	7/30/98	*Intele-Modem*	land	*Mobility*	Aeon	digital	Half	errors everywhere. Plenty of L/F and character alignment propagation error blocks	27.27%	16.40%
17	7/30/98	*Mobility*	Aeon	*Mobility*	land	digital	Full	one small char alignment error propagation block, and two medium L/F blocks	3.67%	1.75%
18	7/30/98	*Mobility*	land	*Intele-Modem*	Aeon	analog	Full	one small L/F block	0.10%	0.08%
19	7/30/98	*Intele-Modem*	Aeon	*Mobility*	land	analog	Full	scattered errors plus one big block where most, but not all, characters are just missing	6.39%	5.06%
20	7/30/98	*Intele-Modem*	Aeon	*Mobility*	land	analog	Half	scattered errors, plus one large and two medium L/F blocks	8.95%	3.12%
21	7/30/98	*Intele-Modem*	Aeon	*Mobility*	land	digital	Full	L/F errors all over the place!	24.41%	13.88%
22	7/30/98	*Intele-Modem*	Aeon	*Mobility*	land	digital	Half	scattered errors plus numerous small and one large L/F blocks	6.12%	2.60%
23	7/30/98	*Intele-Modem*	Aeon	*Intele-Modem*	land	digital	Full	scattered errors plus one small L/F block	0.74%	0.54%

24	7/30/98	*Intele-Modem*	Aeon	*Intele-Modem*	land	digital	Half	scattered errors plus one large char alignment error propagation block -- a row of "-" became a row of "A"	5.84%	2.75%
25	7/30/98	*Intele-Modem*	land	*Intele-Modem*	Aeon	digital	Half	scattered errors plus 3 small and one medium L/F blocks	2.19%	1.25%
26	7/30/98	*Intele-Modem*	land	*Intele-Modem*	Aeon	digital	Full	scattered errors plus one medium L/F block	3.00%	1.49%
27	8/26/98	*Intele-Modem*	land	*Intele-Modem*	Aeon	analog	Full	scattered errors plus one small L/F block	0.55%	0.43%
28	8/26/98	*Intele-Modem*	land	*Intele-Modem*	Aeon	analog	Half	scattered errors	0.30%	0.23%
29	8/26/98	*Intele-Modem*	Aeon	*Intele-Modem*	land	analog	Full	scattered errors	0.35%	0.25%
30	8/26/98	*Intele-Modem*	Aeon	*Intele-Modem*	land	analog	Half	no perceptible errors.	0.20%	0.14%
31	8/26/98	*Intele-Modem*	Aeon	*Mobility*	land	analog	Full	scattered errors plus 3 small L/F blocks	0.97%	0.68%
32	8/26/98	*Intele-Modem*	Aeon	*Mobility*	land	analog	Half	scattered errors plus one small L/F block	0.54%	0.21%
33	8/26/98	*Mobility*	Aeon	*Intele-Modem*	land	analog	Full	scattered errors	0.30%	0.21%
34	8/26/98	*Mobility*	Aeon	*Intele-Modem*	land	analog	Half	scattered errors	0.23%	0.09%
35	8/26/98	*Mobility*	Aeon	*Intele-Modem*	land	digital	Full	scattered errors plus one or two very small L/F blocks	0.73%	0.51%
36	8/26/98	*Mobility*	Aeon	*Intele-Modem*	land	digital	Half	scattered errors	0.73%	0.45%

Error Block Size Key:

small error blocks	< 8 characters
medium error blocks	8 - 20 characters
large error blocks	> 20 characters

APPENDIX J

~~EIA~~ STANDARDS PROJECT PN-1663

TELECOMMUNICATIONS DEVICES

FOR THE DEAF

DRAFT 9

NOTE:

|	Indicates new or revised material
	Indicates item still under discussion

JUNE, 1986

Prepared by the EIA Engineering Committee TR-41

Ad Hoc Committee on Telecommunications Devices for the Deaf

Electronic Industries Association

May 16, 1988

TO: PARTIES INTERESTED IN EIA STANDARDS PROJECT PN 1663,
TELECOMMUNICATIONS DEVICES FOR THE DEAF

In 1981, EIA Engineering Committee TR-41 undertook the writing of a voluntary industry standard for telecommunications devices for the deaf. Our intent at that time was to originate a standard which would provide compatibility and minimum performance criteria for these specialized devices. This effort was considered to be in the public interest both for the purpose of ensuring interoperability of TDDs and to optimize TDD operation on the Public Switched Telephone Network (PSTN).

As commercial interest in these devices has diminished, we now find ourselves in a situation where only two manufacturers remain in the market, and they seem unwilling or unable to agree on the terms of the standard. There has been no movement on this standard project since June of 1986. Accordingly at its March 1988 meeting, TR-41 voted to abandon PN 1663 and directed me to place the existing document, Draft 9, in the public domain and to make it available to any parties wishing to attempt to continue the effort. EIA and its successor organizations will no longer maintain this draft, but will continue to make copies available to qualified persons and organizations for a reasonable period of time. A copy of Draft 9 is enclosed with this letter.

We also have on file copies of Draft 1 (21 pp), Draft 4 (28 pp), and Draft 8 (54 pp) which may be studied by appointment at our offices or which can be photocopied and sent to you at a charge of $ .10 per page. Requests for these copies may be directed to me at:

Telecommunications Industry Association
Suite 4040
1722 Eye Street, NW
Washington, DC 20006
Phone: 202/457-4936
FAX : 202/457-4939

Sincerely,

Peter H. Bennett
Vice President
Telecommunications Industry Association

Enclosure

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

TELECOMMUNICATIONS DEVICES FOR THE DEAF

(From EIA Project Number No. 1663, formulated under the cognizance of EIA TR-41 Committee on Telephone Terminals)

1. INTRODUCTION

1.1 This standard is one of a series of technical standards on telephone terminal equipment issued under the auspices of EIA Engineering Committee TR-41. It has been prepared by an ad hoc committee of manufacturers of Telecommunications Devices for the Deaf (TDDs), representatives of users of these devices, and representatives of the telephone industry, operating under the cognizance of EIA TR-41 Committee on Telephone Terminals. Formation of the ad hoc committee was jointly sponsored by EIA's Telephone Equipment Section and Telecommunications for the Deaf, Inc., Silver Spring, Maryland. This document fills a recognized need in industry brought about by the accelerating trend to replace electromechanical teletypewriters by portable electronic devices as a means by which hearing- or speech-impaired persons may make beneficial use of the public telephone network. It will be useful to anyone engaged in the manufacture of telecommunications devices for the deaf and to those purchasing, operating or using such equipment or devices.

1.2 The standard establishes performance and compatibility requirements for the interoperation of TDDs with a dial-up public or private-line telephone network connection as the transmission medium. As such, it has been necessary in some cases to make compromises between optimum conditions for the operation of the devices and the need for the public telephone network to carry these signals without interference to other users.

1.3 In accordance with EIA Engineering Publication EP-7, two categories of performance standards are specified, mandatory and advisory. The mandatory performance criteria are designated by the word "shall" and the advisory criteria by the words "should", "may", or "desirable" (which are used interchangeably in this standard). The mandatory criteria generally apply to safety, protection, signaling, and compatibility. They specify the absolute minimum acceptable performance levels in areas such as transmission and equipment parameters and durability.

1.4 Advisory or desirable criteria represent product goals. In some instances, these criteria are included in an effort to assure universal product compatibility with equipment and facilities operational in statistically small quantities. In other cases, advisory criteria are presented when their attainment will enhance the general performance of the product in all its contemplated applications. Where both a mandatory and an advisory level are specified for the same criterion, the advisory level represents a goal currently identifiable as having distinct compatability advantages, performance advantages, or both, toward which future designs should strive.

1.5 As technology and application engineering techniques advance, the criteria contained in this document will become subject to change. Furthermore, the document is intended to be a living document, subject to revision and updating, as warranted by advances in network and equipment technology and design.

2. SCOPE

2.1 This standard defines the minimum signaling, protocol, and interface requirements necessary for the successful interoperation, through the switched telephone network, of TDDs and specialized modems intended for use with teletypewriters in networks providing interactive communications for hearing- and speech-impaired persons. These networks are characterized by the use of five-level Baudot code at a nominal speed of 45 baud, half-duplex transmission, and tone frequency conventions of 1400 Hz for mark and 1800 Hz for space.1/

In addition, this standard provides criteria for the signaling, protocol, interface, and keyboard content of TDD equipment which provides optional operation using ASCII seven level codes and "Bell 103" compatible frequencies. The criteria are applicable, however, only when applied to a TDD product which also provides Baudot operation as described above.

2.2 This standard covers TDD'S intended for use with telephones meeting the requirements of RS-470, Telephone Instruments for Voiceband Applications (Ref: A1). Criteria are provided for devices using acoustic coupling to the telephone handset and for devices connected to the telephone line in parallel with the telephone. Acoustic coupling criteria are based on the handsets used with 500-type or similar telephones and may not provide for coupling to "decorator" type telephones.

2.3 Other arrangements are possible but are not covered by this standard.

2.4 This standard does not apply to terminals intended for other communications such as "electronic mail" terminals.

1/ It is recognized that the 5-level Baudot code employed is not the code of choice for new communications networks and that 45 baud operation does not efficiently utilize the capabilities of a voice grade telephone connection. The use of the Baudot code at this rate in conjunction with modems using 1400 and 1800 Hz is widespread by hearing- and speech-impaired persons presently using the telephone network and is described by Dr. Robert H. Weitbrecht in U.S. Patent RE27595. This TDD standard is not limited, however, to the specific protocols utilized by Dr. Weitbrecht.

2.5 Requirements in this standard designated by the parenthetical expression (REN) assume a Ringer Equivalence Number of 1.0. If the TDD has a REN other than 1.0, the stated requirements shall be scaled appropriately, consistent with the definition of REN given in Part 68 of the FCC Rules and Regulations (Ref: A2). Examples of the scaling procedure can be found in section 5.1 of the application notes in this standard.

2.6 This standard is intended to be in conformity with Part 68 of the FCC Rules and Regulations, but is not limited to the scope of those rules.

3. DEFINITIONS

This section contains definitions of terms needed for the proper understanding and application of this standard which are not believed to be adequately treated elsewhere. A glossary of telephone terminology, which will be published as a companion volume to the series of technical standards on Telephone Terminals, is recommended as a general reference and for definitions not covered in this section.

Acoustic Coupling

Acoustic coupling is a means of coupling a signal generated by auxiliary equipment to a dial-up public or private-line telephone network using the telephone handset as the network interface and an audio tone or tones for the transfer of information.

ASCII

ASCII is an acronym for American Standard Code for Information Interchange (Ref: A3). This standard defines the code for a character set to be used for information interchange between equipment of different manufacturers and is a standard for data communication over telephone lines.

Baudot Code

Baudot code is a code for the transmission of data in which five equal-length bits represent one character. This code is used in TDDs with one start bit and one or more stop bits added.

TDD

TDD is an abbreviation for Telecommunications Device for the Deaf. These devices are machines capable of information interchange between compatible units using dial up or private-line telephone network connections as the transmission medium. ASCII or Baudot codes are used by these units.

4. TECHNICAL REQUIREMENTS

TDDs shall provide for either acoustic coupling to a telephone handset or direct connection to the telephone line. Provision of both acoustic coupling and direct connection is permissable. When both are provided the TDD shall be arranged so that only one type of coupling is active at any given time.

4.1 Acoustic Coupling

[Requirements in Section 4.1 apply to TDDs which are acoustically coupled. See section 4.2 for requirements for direct coupled devices.]

TDDs provided with acoustic coupling may incorporate the acoustic coupler in the TDD unit or provide the coupler as a separate module. The coupler shall be designed to accept the handsets used with generic 500-type telephone sets.

4.1.1 Magnetic Coupling

The receiver of the acoustic coupler shall rely only on the acoustic signal from the handset. The magnetic field associated with the receiver of some handsets is not suitable for coupling.

4.1.2 Sidetone

TDDs employing acoustic coupling shall be arranged so that the sidetone provided by the telephone does not cause errors in the operation of the device.

4.1.3 Transmit Signal Levels

4.1.3.1 Requirements

The maximum transmitted signal level shall be -10 dBm$\pm$1dB for Baudot or ASCII answer operation. This requirement applies to the mark and space frequencies individually and to a 3 second average reading of a repeated test character string. The maximum transmitted signal level shall be -12 dBm$\pm$3dB for ASCII originate operation.

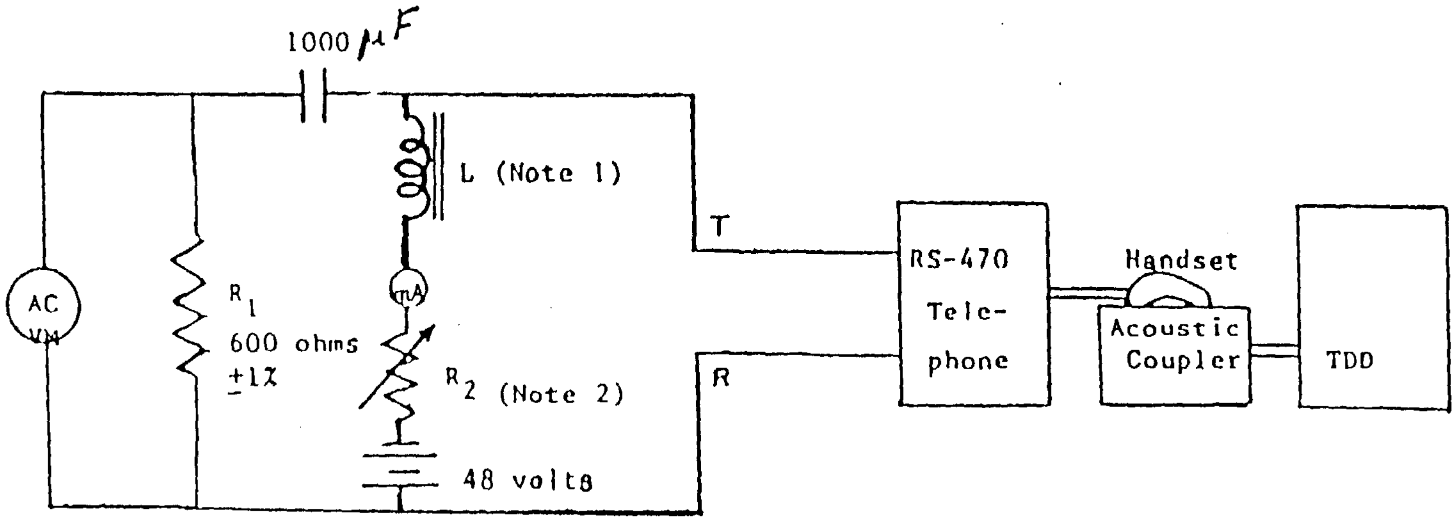
4.1.3.2 Method of Measurement

The transmit signal levels shall be measured using the circuit of Figure 1A with the loop current adjusted to 90 milliamperes. The test character string for Baudot code shall be the repeated characters R and Y. For ASCII code, it shall be repeated letter U. The test character strings provide alternating marks and spaces in the data bits. For ASCII code, test both originate and answer modes.

The telephone set used in the test circuit shall meet the requirments of EIA RS-470 and will have a transmit acoustic to electrical sensitivity at the six frequencies below determined by curve Figure 1B when 6 dB Pa is applied to the microphone:

1070 Hz	1800
1270	2025
1400	2225 Hz

Measurement results made using a calibrated telephone set not meeting these points shall be adjusted to reflect the difference.



Notes;

1. Inductance of battery feed coil, L, at maximum current must be at least 5 H and resistance must be less than 400 ohms.

2. R_2 plus the resistance of the battery feed coil must be adjustable from 400 to 1740 ohms.

3. ACVM shall be a high impedance meter.

FIGURE 1A TDD TO LINE TEST CONFIGURATION

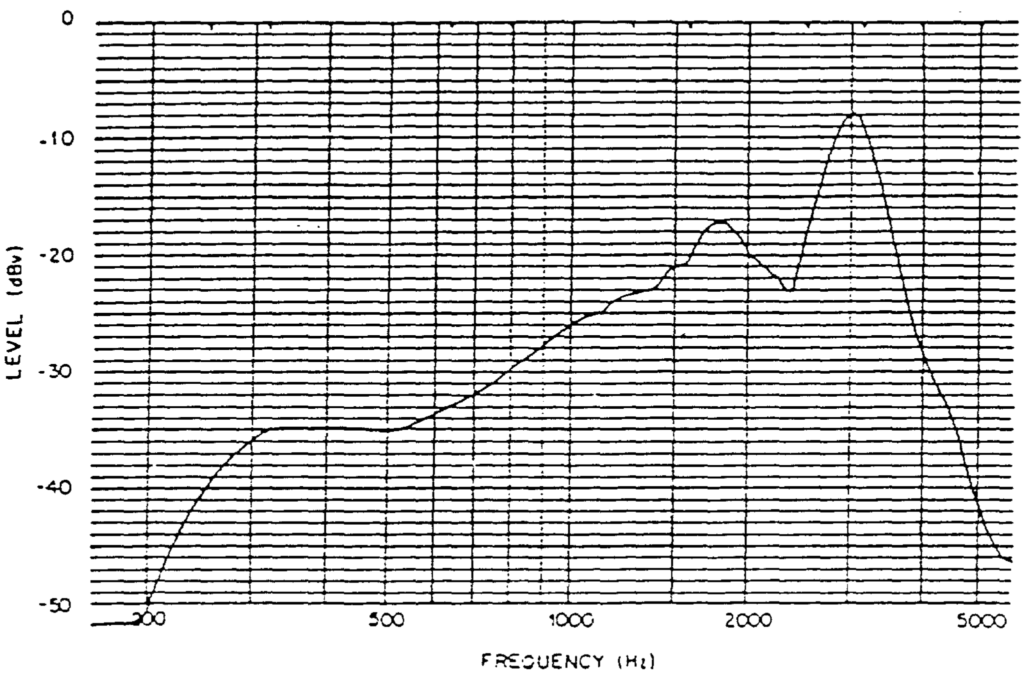


FIGURE 1B RESPONSE CURVE FOR STANDARD TELEPHONE

4.1.4 Receive Signal Levels

It should be noted that sensitivity levels better than those specified may cause unintended characters to be received during noisy idle line conditions. This may be aggravated by high impulse noise present on some telephone lines. It is desireable that sufficient noise immunity be designed into such receivers to prevent the TDD from printing and/or displaying spurious characters during these noise conditions.

The receive signal levels shall be tested using the test setup shown in Figure 2. The test telephone shall conform to the requirements of RS-470 (Ref: A1), and have a receive electrical to acoustic sensitivity at 1000 Hz of 17 dB Pa when 0 dBm is applied to the tip and ring. With the loop current adjusted to 90 ±1 milliamperes, the TDD shall correctly receive signals with levels from -5 dBm to -45 dBm with a signal to noise ratio of 13 dB or greater at the input to the telephone. The line noise shall be white noise as measured at the telephone tip and ring using C-message weighting. Verification shall consist of error free reception of the following message, or equivalent, for a minimum of 120 seconds in a environment with a room ambient noise intensity of 70 dBSPL.

THE QUICK BROWN FOX JUMPED OVER THE LAZY DOG
<FIGS> 123456789 <LTRS> TEST

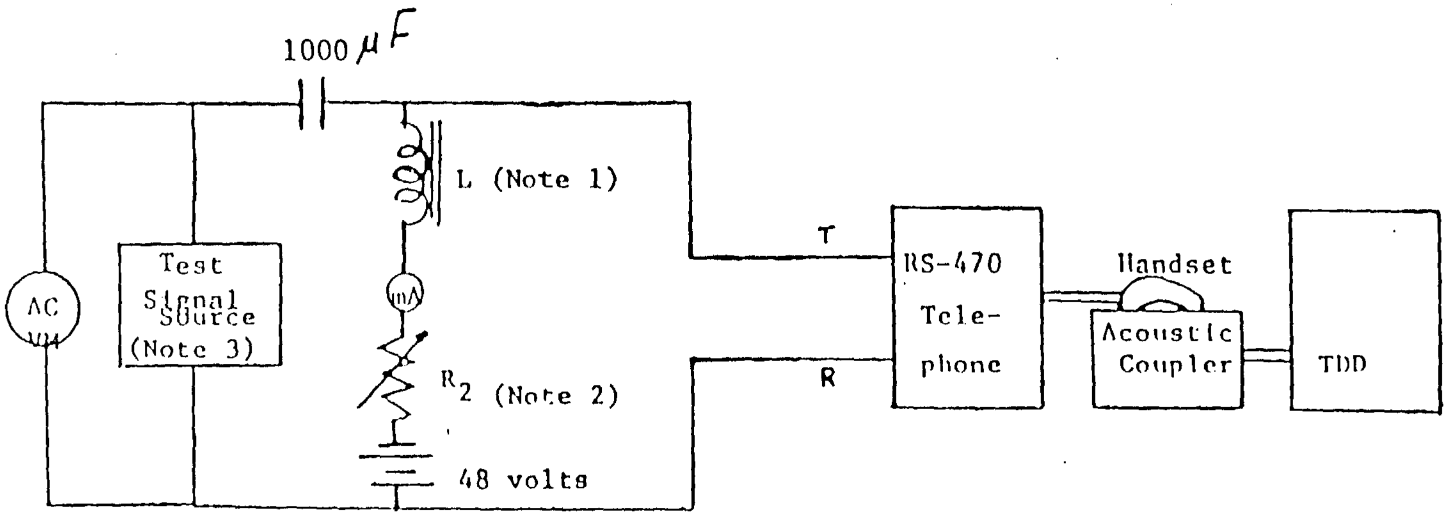
The <FIGS> and <LTRS> characters shall be omitted when testing ASCII code. For ASCII code, these levels shall apply to both the originate and answer modes.

4.1.5 Background Noise Suppression

The acoustic coupler shall be arranged so that background room noise of 70 dBSPL shall result in less than -40 dBm when measured with the test circuit of Figure 1A, with the loop current adjusted to 90 ±1 milliampere. This shall be measured with the TDD turned off.

4.1.6 TDD Noise

TDD noise with acoustic coupling is the internally-generated noise appearing at the acoustic output of the TDD. The noise shall not exceed -35 dBm when measured using the test arrangement of Figure 1A with the loop current adjusted to 90 ±1 milliamperes. The TDD noise should be measured with the TDD turned on but with no signal tones present. The measurement shall be taken over a minimum period of 5 seconds.



Notes:

1. Inductance of battery feed coil, L, at maximum current must be at least 5 H and resistance must be less than 400 ohms.

2. R_2 plus the resistance of the battery feed coil must be adjustable from 400 to 1740 ohms.

3. Test signal source should have an output impedance of 600 ohms $\pm 10\%$.

Figure 2 Test Configuration for Line to TDD

4.1.7 Signal Power Near 2600 Hz

Excessive signal power in the 2450 to 2750 Hz band in the absence of sufficient power in the 800 to 2450 Hz guard band can result in false disconnect or transmission interruption. The following requirement applies to all signals which the TDD may generate or cause to be generated (e.g., by a character sequence).

4.1.7.1 Method of Measurement

Measure the power transmitted by the TDD when acoustically coupled to a telephone set as shown in Figure 1A. Adjust the loop current to 90 ± 1 milliamperes. The power in the 2450 to 2750 Hz band shall (a) not exceed -50 dBm or (b) alternatively, be at least 14 dB below the power in the 800 to 2450 Hz band. These requirements shall not be exceeded for more than 40 milliseconds more often than once in 15 minutes and should not be exceeded for an interval greater than 150 milliseconds more often than once an hour.

It is desirable that the power in the 2450 to 2750 Hz band not exceed -40 dBm at any time.

Note: In demonstrating compliance, it is desirable that the 2450 to 2750 Hz band be defined by a bandpass filter having a 3 dB point (3dB loss relative to midband loss) at a frequency of 2450 Hz or lower and a 3 dB point at a frequency of 2750 Hz or higher. It is desirable that the 800 to 2450 Hz band be defined by a bandpass filter having a 3 dB point at a frequency of 800 Hz or higher and a 3 dB point at a frequency of 2450 Hz or lower. The midband loss of the filter defining the 2450 to 2750 Hz band shall be less than or equal to the midband loss of the filter defining the 800 to 2450 Hz band, when transmitting the test signal in 4.1.3.

4.2 Direct Connection

[Requirements in Section 4.2 apply to TDDs which are directly connected to the telephone network.]

TDDs designed for direct connection to the telephone line in parallel with a standard telephone shall meet the requirements of this section and all its subsections. The telephone shall be used for originating calls and providing an alerting signal on incoming calls. TDDs designed for direct connection to the telephone line without the use of a telephone in parallel shall meet the requirement of ANSI/EIA 496, Interface between Data Circuit-Terminating Equipment (DCE) and the Public Switched Telephone Network (Ref: A4) instead of the requirements of this section and its subsections.

4.2.1 Loop Supervision Characteristics

Supervisory signals are the means by which a TDD connected in parallel with a telephone answers, holds or releases a connection 2/ or recalls an operator. Since continuity of the dc loop current is not guaranteed, TDDs shall not depend on such continuity for proper operation. Loop current interruptions shall not cause a TDD to make a transition from one state to another.

The following are of interest in the supervision of the suscriber line by the TDD; 1) idle; 2) "talking"; and 3) disconnect.

4.2.1.1 Idle State

The idle state is characterized by the combination of an on-hook condition and the absence of a connection to the transmission path in the CO or PBX. The on-hook condition is defined by the on-hook dc resistance and ac impedance criteria specified in 4.2.2.

In this state no dc potential shall be transmitted from the TDD across the network interface.

4.2.1.2 "Talking" State

The "talking" state is characterized by the combination of an off-hook condition and a connection to a talking path in the CO or PBX. The off-hook condition is defined by the off-hook dc resistance and ac impedance criteria specified in 4.2.3.

While in this state, the TDD at a telephone which has originated a call shall not generate an on-hook signal longer than 100 milliseconds in duration, except to generate a disconnect or a flash signal. When the TDD generates a flash signal automatically, the duration of the on-hook signal shall be between 300 milliseconds and 1 second.

A TDD which has answered an incoming call shall not generate an on-hook signal longer than 10 seconds, except to generate a disconnect signal.

2/ The telephone is used with this arrangement for originating calls and may be used for answering calls. When the telephone is used for originating or answering calls that are then to be switched to the TDD, the TDD must be placed in the off-hook, or busy, state before the telephone is returned to the on-hook, or idle, state. In originating calls, the TDD must remain in the idle state until the completion of dialing.

4.2.1.3 Disconnect State

The disconnect state is characterized by an on-hook condition. The on-hook condition is defined by the on-hook dc resistance and ac impedance criteria specified in 4.2.2.

4.2.2 On-Hook Impedances

4.2.2.1 DC Resistance

The on-hook dc resistance is a measure of the idle loop current which the TDD draws from the CO or PBX. The limits are defined by Part 68 of the FCC Rules and Regulations for protection of the telephone network.

The on-hook dc resistance tip to ring, tip to ground, and ring to ground shall be greater than 25 megohms (REN) for values of applied dc voltage to 100 volts and greater than 150 kilohms (REN) in the range from 100 to 200 volts. These values shall apply to both polarities and with the TDD in both the power on and off states except that it shall apply only to the power off state if the TDD design does not allow the on-hook state with the power on.

4.2.2.1.1 Method of Measurement

Connect the TDD tip and ring conductors to a dc source, variable from 0 to 100 volts or from 100 to 200 volts as appropriate. Measure the minimum ratio of dc voltage and current for each voltage range with the TDD power both off and, if the TDD can be in the on-hook state with the power on, with the power on. Reverse the tip and ring connections and repeat the procedure.

Connect in turn, each of the TDD tip and ring conductors to a terminal of the variable dc power supply with the other terminal connected to metal foil which connects all exposed metal surfaces, ground, and all conductors other than the one being tested and the power leads. Determine the minimum voltage-versus-current ratio with power off and if the TDD can be in the on-hook state with the power on, with the power on. Repeat these measurements and calculations with the connections to the variable power supply reversed.

The lowest calculated ratio obtained is the required dc resistance.

4.2.2.2 AC Impedance

The requirements of this section are for a TDD without ring detection intended to be wired in parallel with a telephone used to originate and answer calls. TDDs with ring detection shall meet the alternating current characteristics and ringer sensitivity requirements of RS-470, Telephone Instruments with Loop Signaling for Voiceband Applications. TDDs without ring detection meeting the requirements of this section will work with all of the ringing types specified in EIA RS-470.

4.2.2.2.1 Tip to Ring During Ringing

The on-hook ac tip-to ring- impedance shall be greater than 10 kilohms (REN) over the frequency range of 15.3 to 68 Hz for ac voltages from 40 to 150 Vrms superimposed on up to 105 Vdc of either polarity. The total dc current flow as a result of the ac voltage shall not exceed 0.6 mA (REN), and it is desirable that it not exceed 0.2 mA (REN).

4.2.2.2.2 Tip to Ring During Quiescent State

The on-hook ac tip-to-ring impedance in the absence of ringing shall be in the acceptable region as shown in Figure 3 and Figure 4.

4.2.2.2.3 Tip and Ring to Ground During Ringing

The on-hook ac tip-to-ground and ring-to-ground impedances shall be greater than 100 kilohms over the frequency range of 15.3 to 68 Hz for ac voltages of 40 to 150 Vrms superimposed on up to 105 Vdc of either polarity.

4.2.2.2.4 Tip and Ring to Ground Quiescent State

The on-hook ac tip-to-ground and ring-to-ground impedances shall be greater than 20 kilohms over the frequency range 60 to 660 Hz for voltages up to 50 Vrms.

4.2.3 Off-Hook Impedances

4.2.3.1 DC Resistance

The upper limit for the dc resistance between tip and ring of a direct-connected TDD is determined by the ability of the device to draw adequate current for control of CO relays over a range of loop resistance and CO battery voltage. More current is required for the on-hook to off-hook transition than holding an off-hook connection (where the CO relays are required only to hold their energized state). The lower limit from tip-to-ground and ring-to-ground is necessary to limit unnecessary ground current flow.

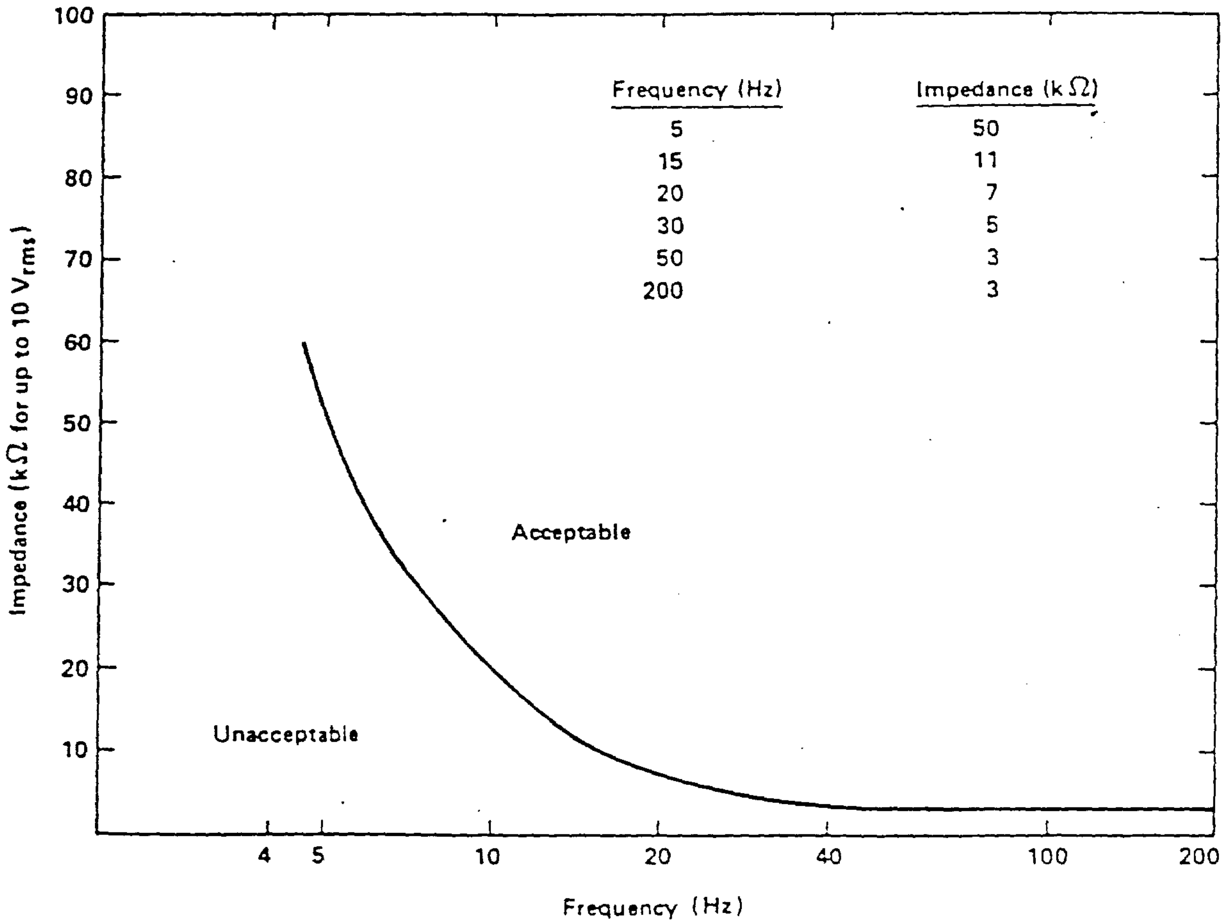


FIGURE 3 ON-HOOK TIP-TO-RING IMPEDANCE
5 TO 200 HZ DURING QUIESCENT STATE

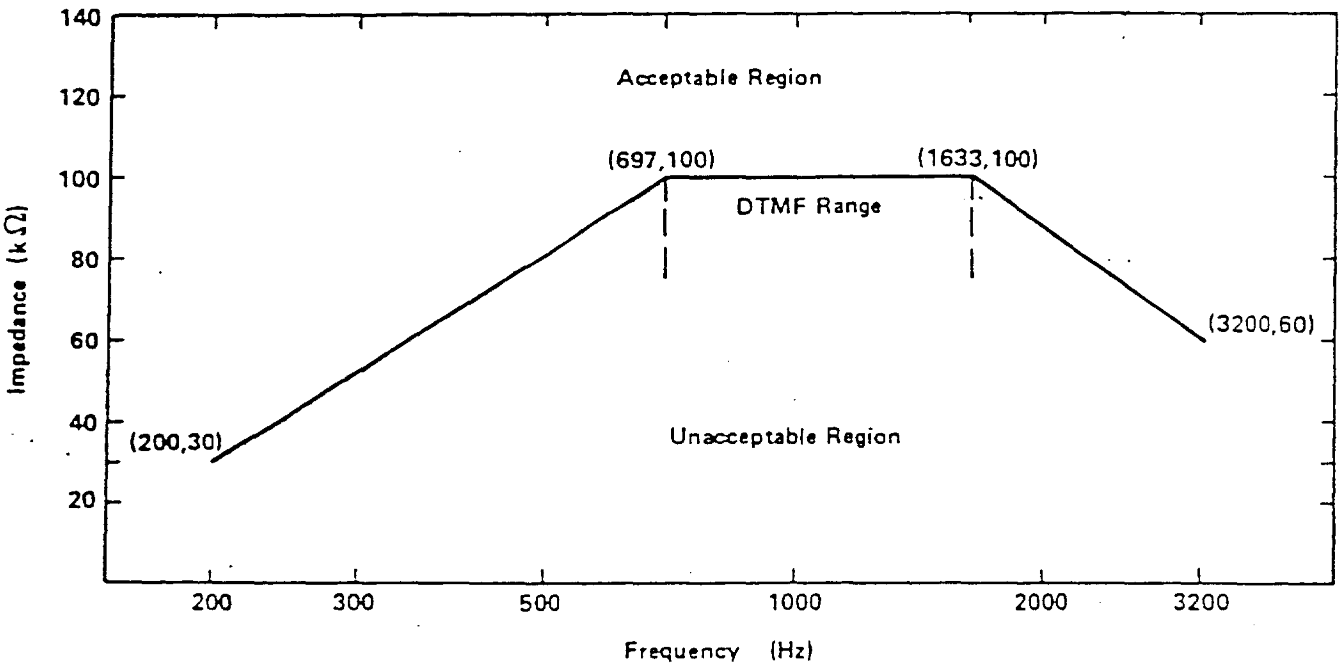


FIGURE 4 ON-HOOK TIP-TO-RING IMPEDANCE
200 TO 3200 HZ DURING QUIESCENT STATE

4.2.3.1.1 Tip-to Ring

The off-hook tip-to-ring dc voltage-versus-current characteristics shall conform to the notes of Figure 5. In addition, over the range of loop currents specified in the simulator circuit of Figure 6, the loop current shall, for at least 5 seconds after the TDD goes to the off-hook state, when responding to ringing (called party off-hook condition), either exceed the current which would flow through a 200-ohm termination, or not decrease by more than 25 pecent from the maximum current during this 5 second interval, unless the equipment is returned to the on-hook state during that 5-second interval.

4.2.3.1.2 Tip-to-Ground and Ring-to-Ground

The off-hook dc resistance from tip-to-ground and ring-to-ground of the TDD shall be greater than 250 Kilohms (REN).

4.2.3.1.3 Method of Measurement

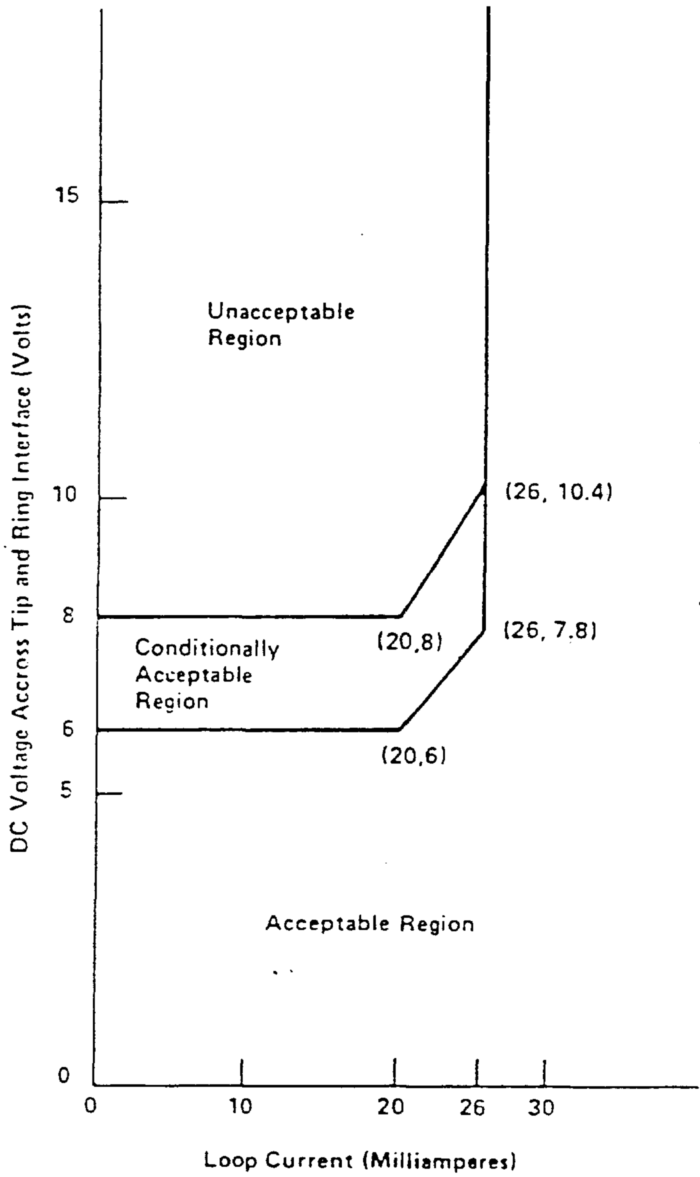
The off-hook dc resistances of the TDD shall be tested in accordance with IEEE Standard 269-1983, Method of Measuring Transmission Performance of Telephone Sets (Ref: A5).

4.2.3.2 AC Impedance

Singing and barrel effect result in distortion of the signal when the TDD impedance is significantly different from the line impedance at the interface. A measure of this discontinuity can be determined by return loss defined as follows:

$$\text{Return Loss (dB)} = 20 \log \left|(Z1+Z2)/(Z1-Z2)\right|$$

where Z1 and Z2 are the two impedances at the interface.



Notes:

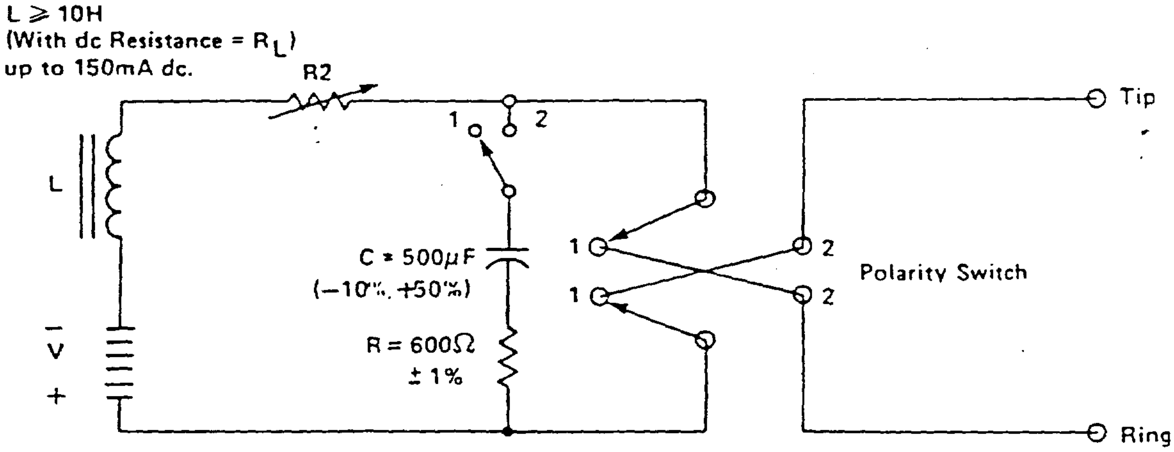
1. This figure characterizes the voltage-versus-current limits of the telephone set, as measured at the tip and ring interface while the telephone set is disassociated from the central office or PBX line.

2. On simulated outgoing calls operation shall fall within the Acceptable Region during the On-Hook to Off-Hook transition and during the make interval of rotary dial pulsing.

3. On simulated outgoing calls operation may fall within the Conditionally Acceptable Region during DTMF signaling and after called party answer.

4. On simulated incoming calls, operation shall fall within the Acceptable Region for at least one second after answer; after one second operation is allowed in the Conditionally Acceptable Region for remainder of the call.

FIGURE 5 OFF-HOOK TIP-TO-RING
VOLTAGE VS. CURRENT CHARACTERISTICS



Condition	Volts		Polarity Switch	R2 + R_L Continuously Variable Ohms
	Min.	Max.		
1	42.5	56.5	1 and 2	400 to 1740
2	105		2	1300 to 2000

FIGURE 6 LOOP SIMULATOR FOR LOOP START CIRCUITS

4.2.3.2.1 Requirement

The return loss of a TDD at the tip and ring terminals measured against a 600-ohm resistor shall be greater at each frequency than the following, over the range of loop currents provided by the loop simulator of Figure 6.

Frequency (Hz)	Minimum Return Loss (dB)
200-3200	3.5
500-2500	7.0

It is desirable that the off-hook impedance be 600 ohms, across the 200-to-3200 Hz band.

4.2.3.2.2 Method of Measurement

Connect the TDD and a suitable dc supply circuit as in Figure 7 and measure the return loss against 600 ohms over the loop conditions specified in Figure 6.

4.2.4 Longitudinal-to-Metallic Balance

The longitudinal-to-metallic balance is defined as:

$$\text{Longitudinal Balance (dB)} = 20 \log \left| Vs/Vm \right|$$

where Vs is the disturbing longitudinal voltage and Vm the resulting metallic voltage at the same frequency.

4.2.4.1 Requirement

The longitudinal-to-metallic balance shall be in the allowable region of Figure 8 at all frequencies from 60 to 4000 Hz over the range of loop currents provided by the loop simulator of Figure 6. This balance shall be met for both the on-hook and off-hook states.

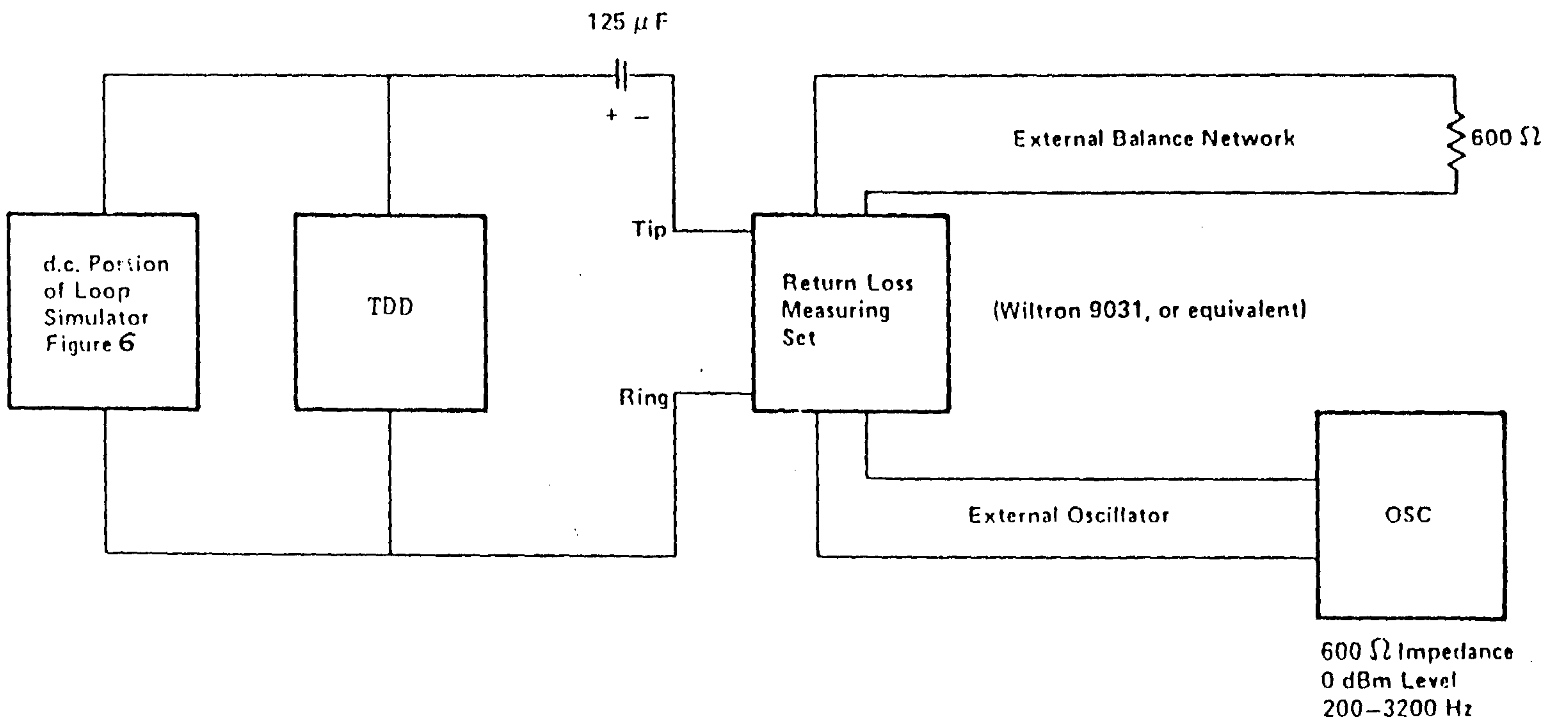


FIGURE 7 RETURN LOSS TEST CONFIGURATION

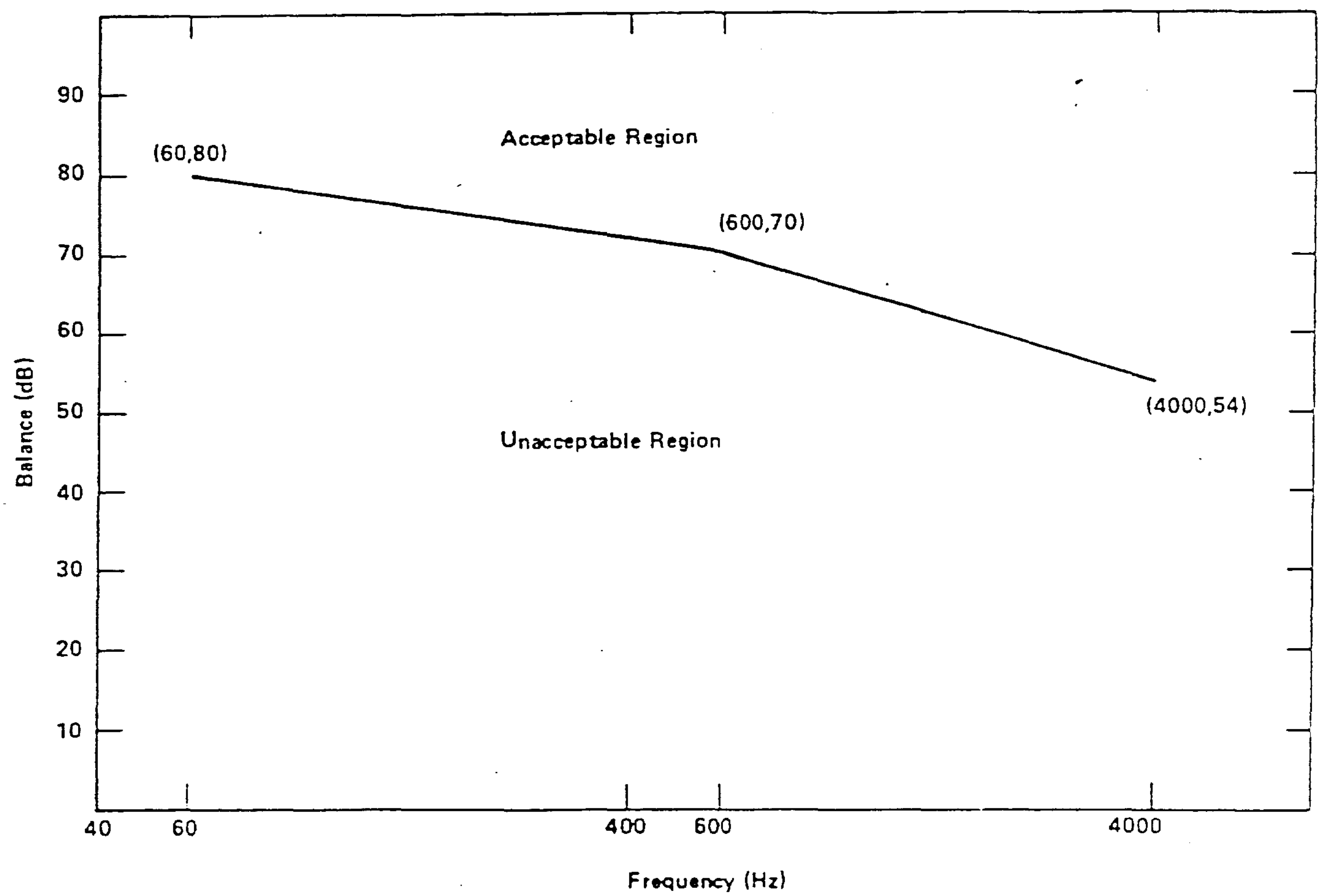


FIGURE 8 LONGITUDINAL BALANCE REQUIREMENTS

4.2.4.2 Method of Measurement

The TDD shall be tested in accordance with IEEE Standard 455-1976, Measuring Longitudinal Balance of Telephone Equipment Operating in the Voice Band (Ref: A6), with the following recommendations:

(1) The alternating current source (Section 9.2.1 of 455-1976) should be capable of generating frequencies up to and including 4 kHz.

(2) A frequency selective voltmeter (Section 9.2.2 of 455-1976) is used.

The test shall be conducted for both the on-hook and off-hook states. The on-hook test should be made with the power both on and off if the TDD can be in the on-hook state with the power on.

4.2.5 Metallic-to-Longitudinal Balance

Metallic-to-longitudinal balance is specified in Part 68 of the FCC Rules and Regulations to insure that a metallic signal is not converted into a longitudinal signal which could cause excessive noise in other pairs of a multipair cable.

The metallic-to-longitudinal balance is defined as:

$$\text{Longitudinal Balance (dB)} = 20 \log \left| Vm/Vs \right|$$

where Vs is the longitudinal voltage produced across a 500-ohm longitudinal termination and Vm is the metallic voltage across the tip and ring interface of the terminals of the TDD when a voltage (at any frequency in the specified frequency range) is applied from a balanced 600-ohm metallic source.

4.2.5.1 Requirement

The minimum metallic-to-longitudinal balance for a TDD, both on-hook and off-hook and under all loop conditions, shall satisfy the following:

Frequency Range (Hz)	Minimum Balance (dB)
200 - 1000	60
1000 - 4000	40

The TDD shall meet or exceed the minimum balance requirements under all reasonable applications of ground to exposed conductive surfaces of the equipment, with all possible interface lead terminations which may affect compliance, connected to external ground.

4.2.5.2 Method of Measurement

The test procedure is outlined in Part 68 of the FCC Rules and Regulations. A test circuit that satisfies the stated conditions is shown in Figure 9. On-hook measurements should be made with the TDD power both on and off if the TDD can be in the on-hook state with the power on.

4.2.6 TDD Noise

TDD noise, with direct coupling, is the internally-generated noise present at the tip and ring terminals of the TDD. It is defined as the weighted signal power delivered to a specified termination in the absence of a transmitted signal.

4.2.6.1 Off-Hook Noise

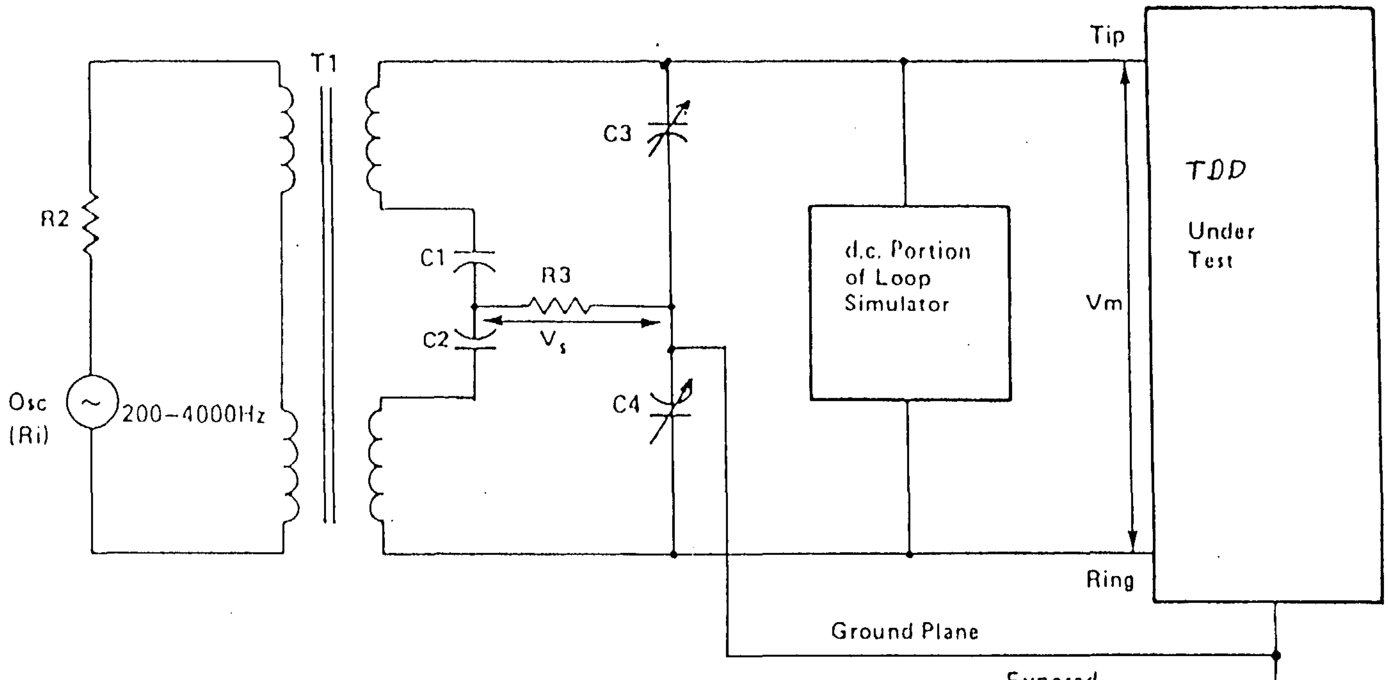
The TDD noise in the off-hook, or active, state shall not exceed 15 dBrnC. The TDD noise shall be measured using the test circuit shown in Figure 7 of IEEE Standard 269-1983 using a noise meter as specified in Section 5.14 of IEEE 269-1983. The noise shall be measured under the following loop current conditions:

mA
90
60
30

During the noise measurement no signal shall be transmitted. The measurement shall be taken over a minimum period of 5 seconds.

4.2.6.2 On-Hook Noise

In the TDD on-hook, or idle, state, the power delivered into the loop simulator circuit of Figure 6 shall not exceed -55 dBm within the frequency band 200 to 4000 Hz and shall not exceed 10 dBrnC.



T_1	–	WECo #111C or 119E, or ADC # 118F, or Equivalent
C_1, C_2	–	8 Microfarad, 400 WVDC, Matched to Within 0.1%
C_3, C_4	–	100 to 500 Picofarad Adjustable Trimmer Capacitors
Osc	–	Audio Oscillator with Source Resistance, $R_i \leqslant 600\ \Omega$
R_2	–	Selected Such that $R_i + R_2 = 600\ \Omega$
R_3	–	$500\ \Omega$

NOTES:

1. Vm Shall Not be Measured at the Same Time as Vs
2. Use Trimmer Capacitors C_3 and C_4 to Balance the Test Circuit to 20 dB Greater Balance Than the Equipment Standard for all Frequencies Specified, with $600\ \Omega$ Resistor Substituted for the Equipment Under Test.
3. Exposed Conductive Surfaces on the Exterior of the Equipment Under Test Shall be Connected to the Ground Plane for this Test.

FIGURE 9 METALLIC-TO-LONGITUDINAL BALANCE TEST CIRCUIT

4.2.7 Transmit Signal Power

The transmit signal power for both Baudot and ASCII operation shall be -10 dBm ±1 dB. This requirement applies to the mark and space frequencies individually and to a 3-second average reading of a repeated test character string. The test character string for Baudot code shall be the repeated character string RYRYRY. For ASCII code, it shall be repeated U's. These test character strings provide alternating marks and spaces in the data bits. For ASCII, this requirement applies to both the originate and answer modes. The power shall be measured with the TDD connected in place of the telephone in Figure 1.

4.2.8 Receive Signal Power

It should be noted that sensitivity levels better than those specified may cause unintended characters to be received during noisy idle line conditions. This may be aggravated by high impulse noise present on some telephone lines. It is desireable that sufficient noise immunity be designed into such receivers to prevent the TDD from printing and/or displaying spurious characters during these noise conditions.

TDDs employing direct coupling shall accept signals between -5 dBm and -45 dBm at the input to the TDD for both Baudot and ASCII operation with a 13 dB or greater signal to noise ratio. These levels apply to both the originate and answer modes for ASCII.

The noise shall be white noise as measured at the tip and ring using C-message weighting.

The levels shall be tested using the test setup shown in Figure 2 with the TDD connected in place of the telephone. Verification shall consist of error free reception of the following message, or equivalent, for a minimum of 120 seconds:

THE QUICK BROWN FOX JUMPED OVER THE LAZY DOG
<FIGS> 123456789 <LTRS> TEST

The <FIGS> and <LTRS> characters shall be omitted when testing ASCII code.

4.2.9 Signal Power Limitations

4.2.9.1 Voiceband Metallic Signal Power in the 200 to 4000 Hz Band

For internal signal sources not intended for network control signaling, the maximum power of other than live voice signals delivered to the loop simulator circuit of Figure 1 shall not exceed -9 dBm, when averaged over any 3-second interval. No manufacturing tolerance is allowed which would permit this power to be exceeded by any TDD. This requirement includes all power delivered to the tip and ring.

For internal sources primarily intended for network control signaling, the maximum power delivered to the loop simulator circuit of Figure 1 shall not exceed 0 dBm when averaged over any 3-second interval, during normal usage. For manually originated dual tone mulitfrequency (DTMF) signals, this limitation applies to the average power with 40 percent duty cycle.

4.2.9.2 Metallic Signal Power in the 3995 to 4005 Hz Band

The maximum power delivered by internal signaling sources (other than those sources intended for network control signaling) in the 3995 to 4005 Hz band to the loop simulator circuit of Figure 1 shall be 18 dB below the maximum permitted power specified in 4.2.9.1 for the 200 to 4000 Hz band.

4.2.9.3 Relative Power of Frequencies Near 2600 Hz

4.2.9.3.1 Billing Protection

During the first 2 seconds after the TDD transfers to an off-hook state on an incoming call (answer) signals from internal sources shall not have power in the 2450 to 2750 Hz band unless at least equal power is present in the 800 to 2450 Hz band. The power of concern in both bands is the power averaged over a 30 milliseconds interval.

Note: In demonstrating compliance, it is desirable that the 2450 to 2750 Hz band be defined by a bandpass filter having a 3 dB point (3dB loss relative to midband loss) at a frequency of 2450 Hz or lower and a 3 dB point at a frequency of 2750 Hz or higher. It is desirable that the 800 to 2450 Hz band be defined by a bandpass filter having a 3 dB point at a frequency of 800 Hz or higher and a 3 dB point at a frequency of 2450 Hz or lower. The midband loss of the filter defining the 2450 to 2750 Hz band shall be less than or equal to the midband loss of the filter defining the 800 to 2450 Hz band.

4.2.9.3.2 False Disconnect Protection

The following requirements apply to an incoming call starting 2 seconds after the TDD has gone to an off-hook state on an incoming call and at all times after the TDD goes to an off-hook state on a call origination. The requirements apply to all signals which the TDD may generate or may be caused to generate (e.g., by a character sequence) in all intended applications and modes of operation. The frequency weighted and full-wave rectified voltage in the 2450 to 2750 Hz band are compared to the greater of (a) the full-wave rectified voltage of a -44 dBm sine wave or (b) the full-wave rectified voltage in the 800 to 2450 Hz guard band when the rectified voltages are averaged and compared is defined by the configuration in Figure 10. The frequency weighting functions for the two bands shall be in the acceptable region of Figures 11 and 12.

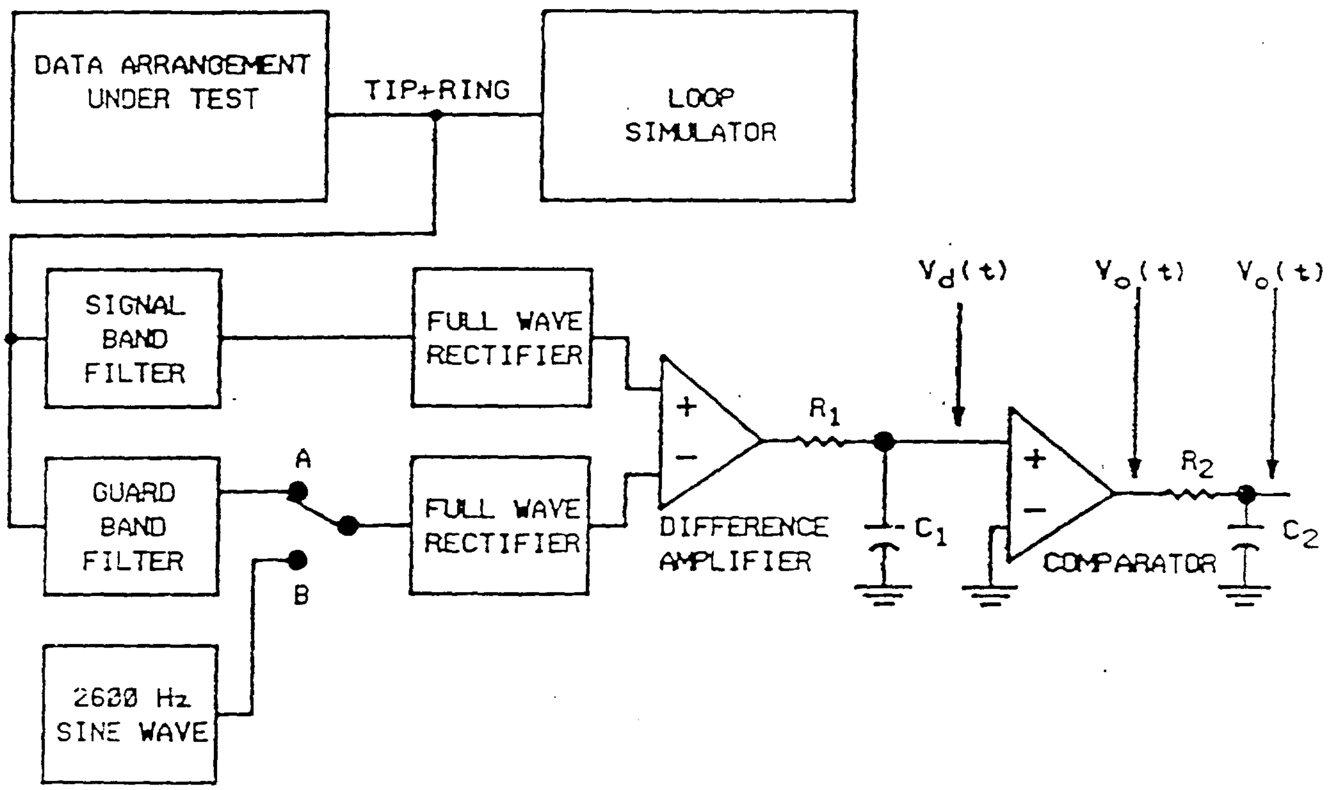
The output voltage Vo(t) of the configuration shown in Figure 10 shall not exceed zero more often than an average of once in fifteen minutes.

The output voltage of the configuration shown in Figure 10 shall not remain intermittently above zero for an interval of greater than 150 milliseconds in duration more often than an average of once in an hour. The voltage is considered to be intermittently above zero providing that, once it exceeds zero, it does not fall below zero for more than 30 milliseconds (i.e., each interval incudes at its end a 30 milliseconds interval during which the voltage is continuously below zero.)

4.2.9.3.3 Protection Against Transmission Interruption

The following requirement, defined in terms of the configuration of Figure 10 with the value of the R2C2 time constant changed to 15 milliseconds, apply throughout the entire duration of a call for all signals which the TDD may generate or may be caused to generate (e.g., by any character sequence), and for all intended applications and modes of operation. Frequency weighting function for the three applicable signal-band filters are defined in Figures 13, 14, and 15. The frequency weighting functions for the two applicable guard-band filters are defined in Figures 11 and 16. The output voltage Vo(t) of the configuration, for the three filter combinations specified below, shall not exceed zero, for any sequence of signals.

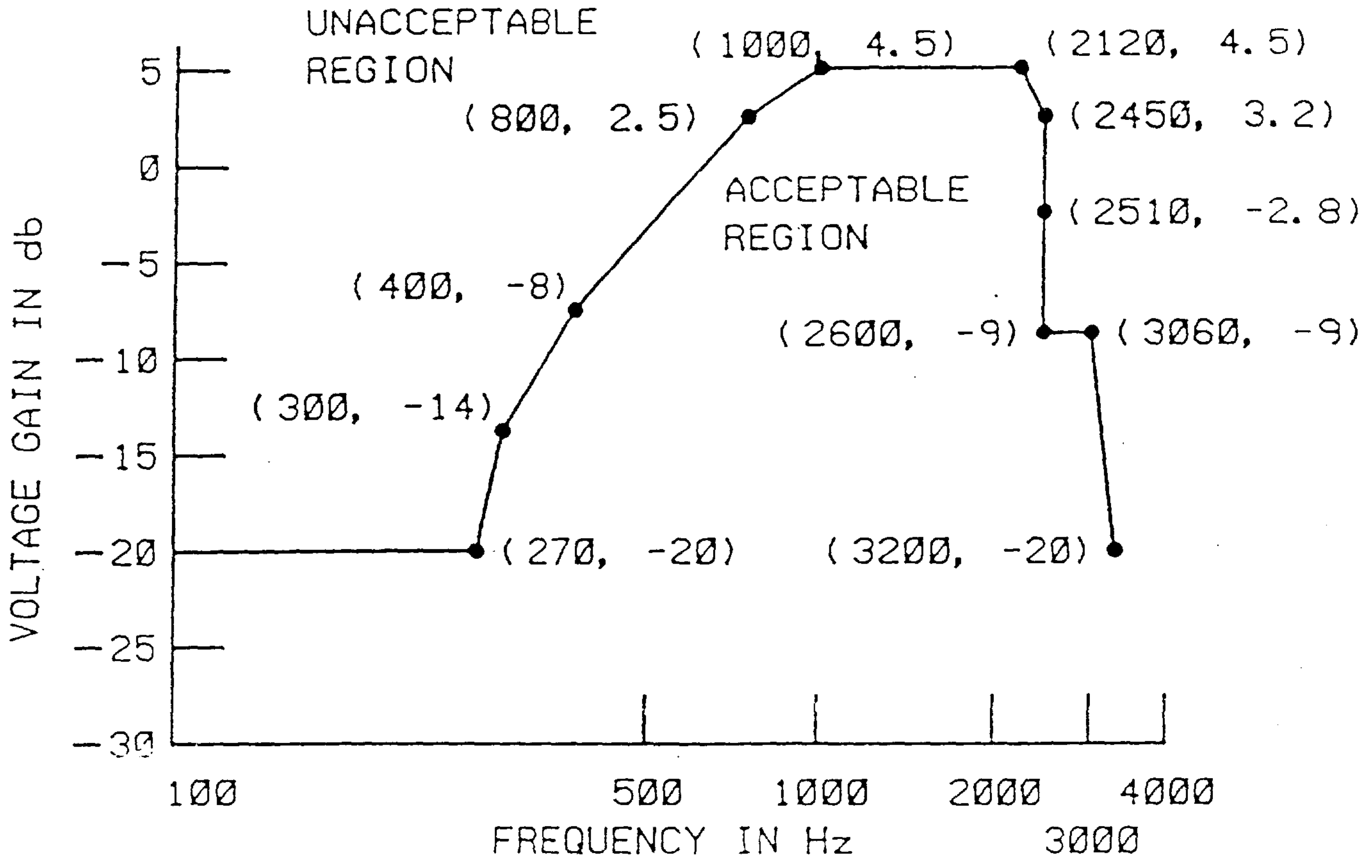
Condition	Signal-Band Filter	Guard-Band Filter
1	Figure 13	Figure 11
2	Figure 14	Figure 11
3	Figure 15	Figure 16



NOTES:

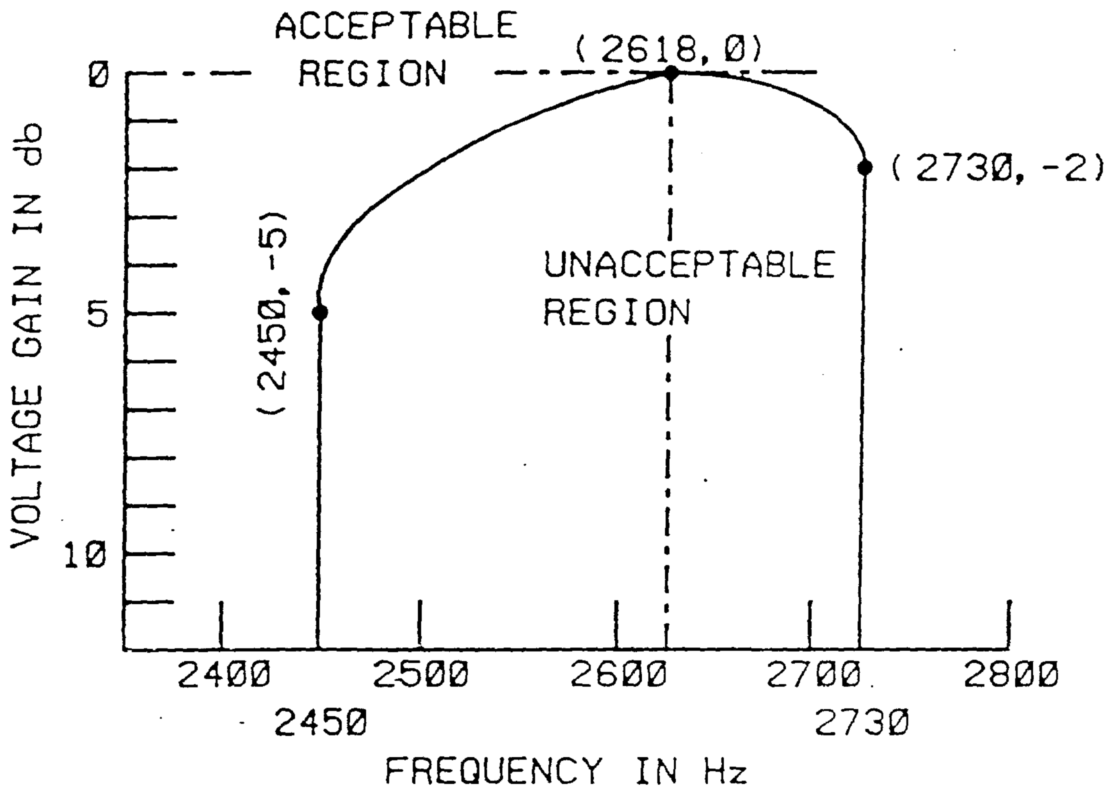
1. THE FILTERS HAVE HIGH INPUT IMPEDANCE
2. $R_1C_1 = 3.5 \pm 0.5$ MILLISECONDS
3. $R_2C_2 < 43$ MILLISECONDS
4. THE 2600 Hz SINE WAVE VOLTAGE IS NOT GREATER THAN 5 MILLIVOLTS RMS
5. $V_o = V$ SIGN (V_d), V IS A CONSTANT
6. EQUIPMENT PASSES THE TEST IF $_0V(t)$ DOES NOT EXCEED ZERO WITH THE SWITCH IN ONE OF ITS TWO POSITIONS (A OR B)

FIGURE 10 SIGNALING INTERFERENCE TEST ARRANGEMENT



THE GUARD BAND FILTER GAIN VS FREQUENCY IS NO GREATER THAN THE GAIN INDICATED BY THE STRAIGHT LINES OF THIS FIGURE. THE NUMBERS IN PARENTHESES ARE FREQUENCY AND GAIN, AND DEFINE THE END POINTS OF THE LINE SEGMENTS.

FIGURE 11 GUARD BAND WEIGHTING FUNCTIONS

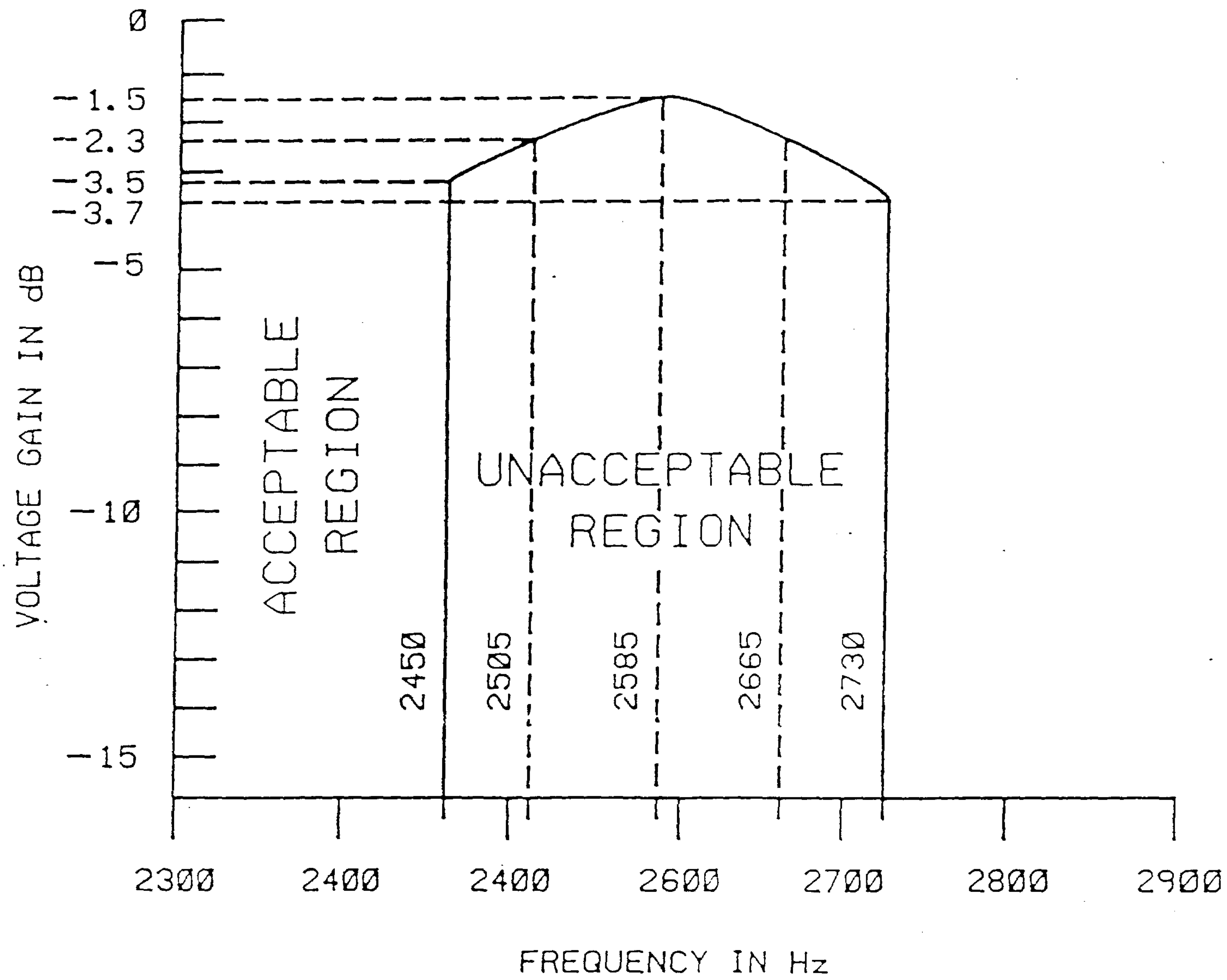


THE SIGNAL BAND FILTER GAIN VS FREQUENCY IS NOT LESS THAN THE GAIN INDICATED BY THIS FIGURE. THE SHAPE OF THE CURVED PORTION OF THE FIGURE IS DEFINED BY:

$$\text{GAIN (dB)} = -1.5 - 10 \log_{10} \left[1 + Q^2 \left(\frac{f}{f_o} - \frac{f_o}{f} \right)^2 \right]$$

WITH Q = 11.3 AND FO = 2618 Hz

FIGURE 12 SIGNAL BAND WEIGHTING FUNCTION

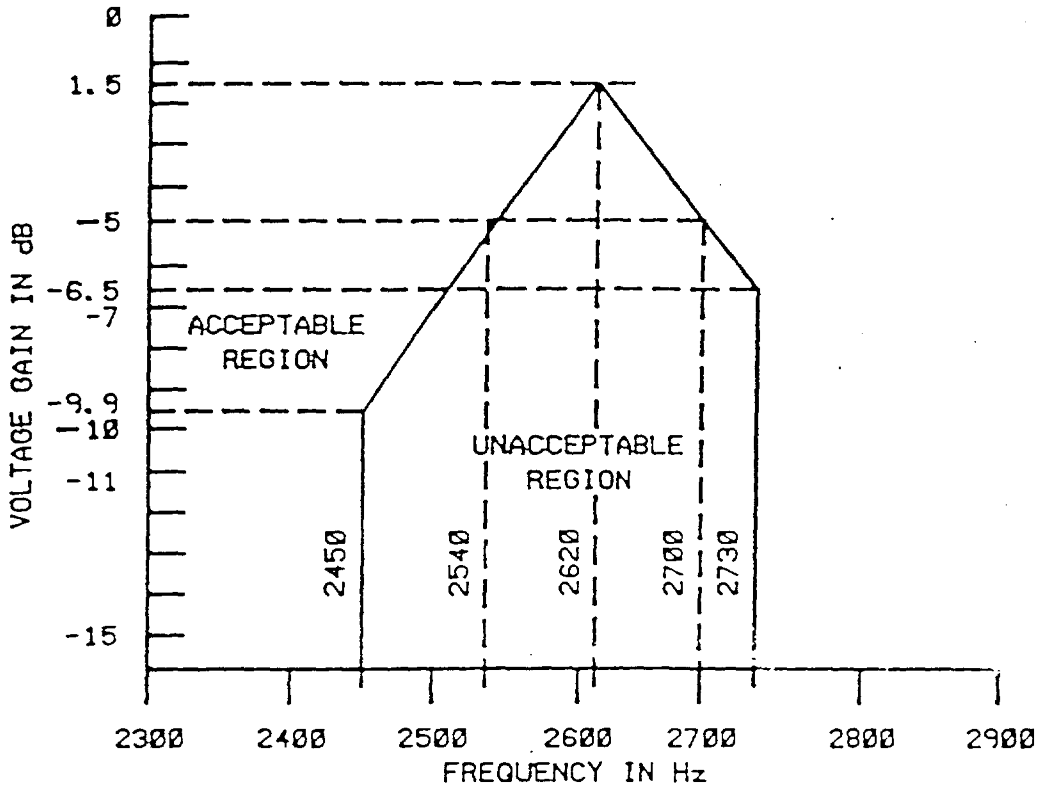


THE SIGNAL-BAND FILTER GAIN VS FREQUENCY IS NOT LESS THAN THE GAIN INDICATED BY THIS FIGURE. THE FIGURE IS DEFINED BY:

$$\text{GAIN (dB)} = -1.5-10 \log_{10} \left[1+Q^2 \left(\frac{f}{f_o}-\frac{f_o}{f}\right)^2\right]$$

WITH $Q = 7.2$ AND $f_o = 2585$ Hz

FIGURE 13 SIGNAL BAND WEIGHTING FUNCTION

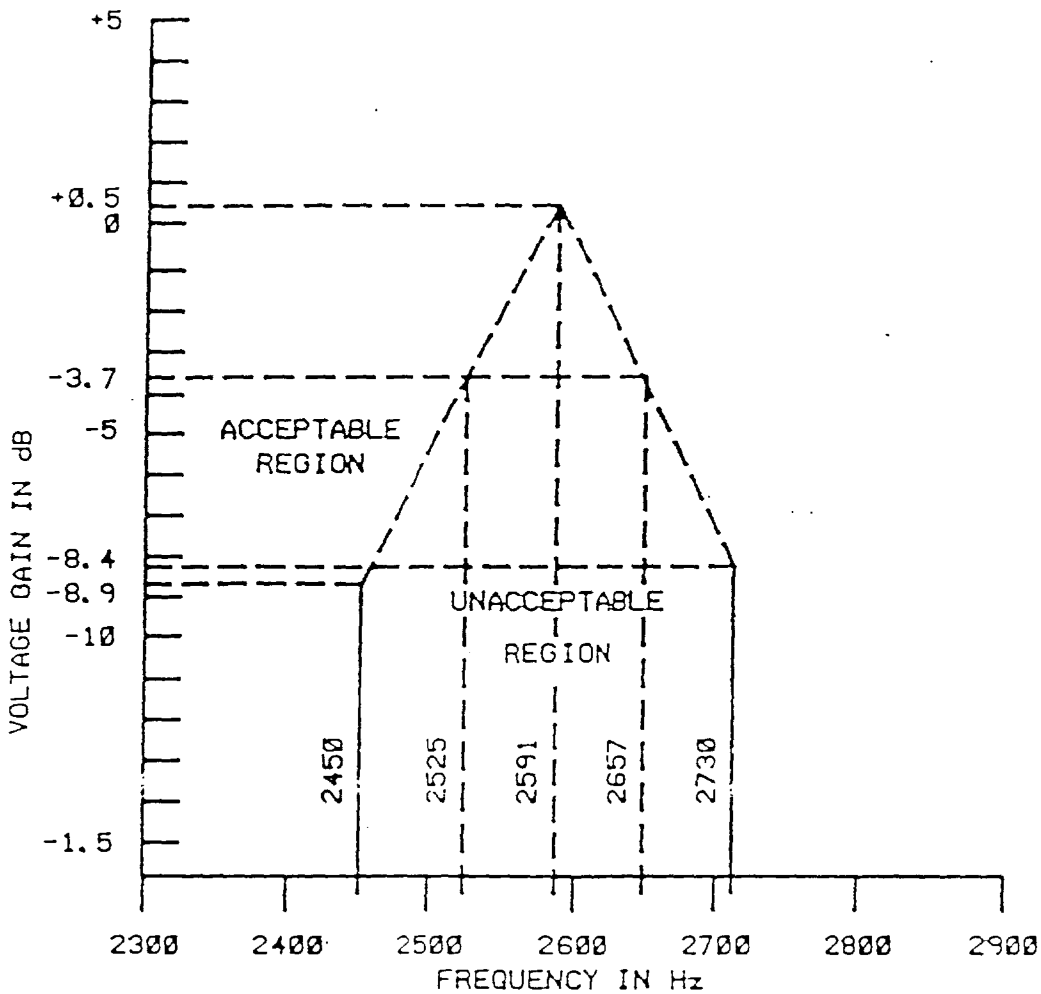


THE SIGNAL-BAND FILTER GAIN VS FREQUENCY IS NOT LESS THAN THE GAIN INDICATED BY THIS FIGURE. THE FIGURE IS DEFINED BY:

$$\text{GAIN (dB)} = -1.5-10\log_{10}\left[1+Q^2\left(\frac{f}{f_o}-\frac{f_o}{f}\right)^2\right]$$

WITH $Q = 18.0$ AND $f_o = 2620$ Hz

FIGURE 14 SIGNAL BAND WEIGHTING FUNCTION

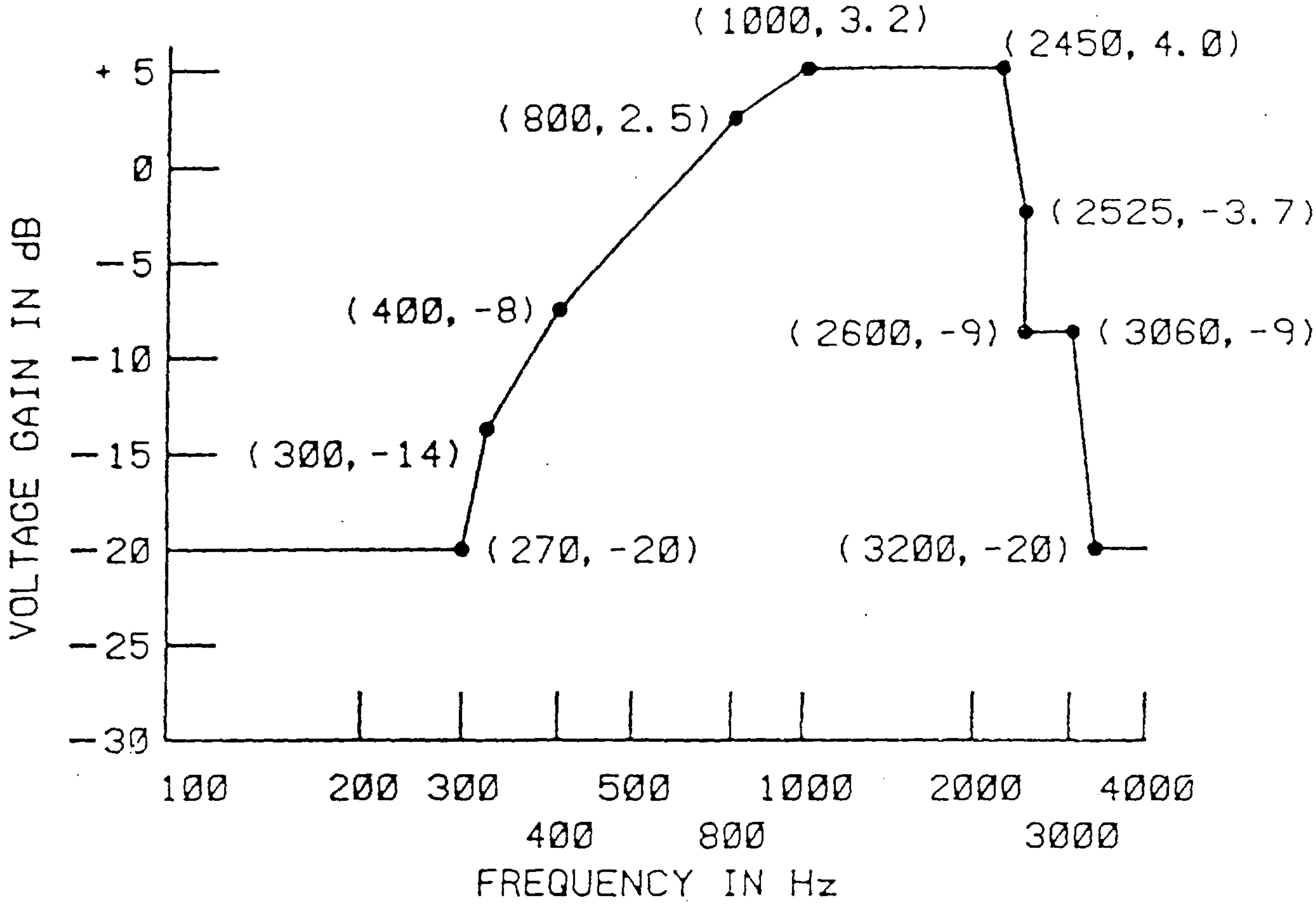


THE SIGNAL-BAND FILTER GAIN VS FREQUENCY IS NOT LESS THAN THE GAIN INDICATED BY THIS FIGURE. THE FIGURE IS DEFINED BY:

$$\text{GAIN (dB)} = +1.5 - 10 \log_{10} \left[1 + Q^2 \left(\frac{f}{f_o} - \frac{f_o}{f}\right)^2\right]$$

WITH $Q = 24.8$ AND $f_o = 2591$ Hz

FIGURE 15 SIGNAL BAND WEIGHTING FUNCTION



THE GUARD BAND FILTER GAIN VS FREQUENCY IS NO GREATER THAN THE GAIN INDICATED BY THE STRAIGHT LINES OF THIS FIGURE. THE NUMBERS IN PARENTHESES ARE FREQUENCY AND GAIN, AND DEFINE THE END POINTS OF THE LINE SEGMENTS.

FIGURE 16 GUARD BAND WEIGHTING FUNCTION

4.2.9.4 Maximum Metallic Voltages in the 4kHz to 270 kHz Band

The root-mean-square voltage 3/ (RMS), averaged over 100 milliseconds, at the tip and ring terminals of the TDD, in all possible 8 kHz bands within the indicated frequency range shall not exceed the maximum indicated below.

Center Frequency of 8 kHz Band	Max RMS Votage in 8 kHz Band Centered at f	Metallic Terminating Impedance
8 kHz to 12 kHz	$-(6.4 + 12.6 \log f)$ dBv	300 ohms
12 kHz to 90 kHz	$(23 - 40 \log f)$ dBv	135 ohms
90 kHz to 266 kHz	-55 dBv	135 ohms

where f is the center frequency in kilohertz of each of the possible 8 kHz bands and dBv is $20 \log_{10}$ (voltage), where voltage is in volts.

4.2.9.4.1 Conditions

The limitations apply in all operating states of the TDD. In the off-hook state, they are applicable over the range of loop current specified in Figure 6. The limitations apply for all possible transmitted signals or character sequences.

4.2.9.5 Maximum Metallic Voltages in the 270 kHz to 6 MHz Band

The root-mean-square value of the metallic voltage components in the frequency range of 270 kHz to 6 MHz shall, averaged over 2 microseconds, not exceed -15 dBv. This limitation applies with a metallic termination having an impedance of 135 ohms and under the conditions of 4.2.9.4.1.

3/ Average magnitudes may be used for signals that have peak-to rms ratios of 20 dB or less. RMS limitations shall be used instead of average values if the peak-to-rms ratio of the longitudinal signal exceeds 20 dB.

4.2.9.6 Maximum Longitudinal Voltage in the 100 to 4000 Hz Band

The weighted root-mean-square voltage 4/ averaged over 100 milliseconds that is the resultant of all the component longitudinal voltages in the 100 to 4000 Hz band after weighting according to the curve in Figure 17 shall not exceed -30 dBv under the conditions stated in 4.2.9.4.1. The weighting curve of Figure 17 has an absolute gain of unity at 4 kHz.

4.2.9.7 Maximum Longitudinal Voltage in the 4kHz to 270khz Band

The root-mean-square voltage 4/, averaged over 100 milliseconds, at the tip and ring of the TDD in all of the possible 8 kHz bands within the indicated frequency ranges shall not exceed the maximum indicated under the conditions of 4.2.9.4.1.

Center Frequency of 8 kHz	Maximum RMS Voltage in 8 kHz Band Centered at f	Longitudinal Terminating Impedance	Metallic Terminating Impedance
8 kHz to 12 kHz	$-(18.4 \div 20 \log f)$DBV	500 ohms	300 ohms
12 kHz to 42 kHz	$(3 - 40 \log f)$ dBV	90 ohms	135 ohms
42 kHz to 266 kHz	-62 dBV	90 ohms	135 ohms

where f is the center frequency in kilohertz of each of the possible 8 kHz bands and dBV is $20 \log_{10}$ (voltage), where voltage is in volts.

4.2.9.8 Maximum Longitudinal Voltage in the 270kHz to 6MHz Band

The root-mean-square value of the longitudinal voltage components in the frequency range of 270 kHz to 6 MHz shall, averaged over 2 microseconds, not exceed -30 dBV when measured with a longitudinal termination having an impedance of 90 ohms under the conditions of 4.2.9.4.1.

4/ Average magnitudes may be used for signals that have peak-to-rms ratios of 20 dB or less. RMS limitations shall be used instead of average values if the peak-to-rms ratio of the longitudinal signal exceeds 20 dB.

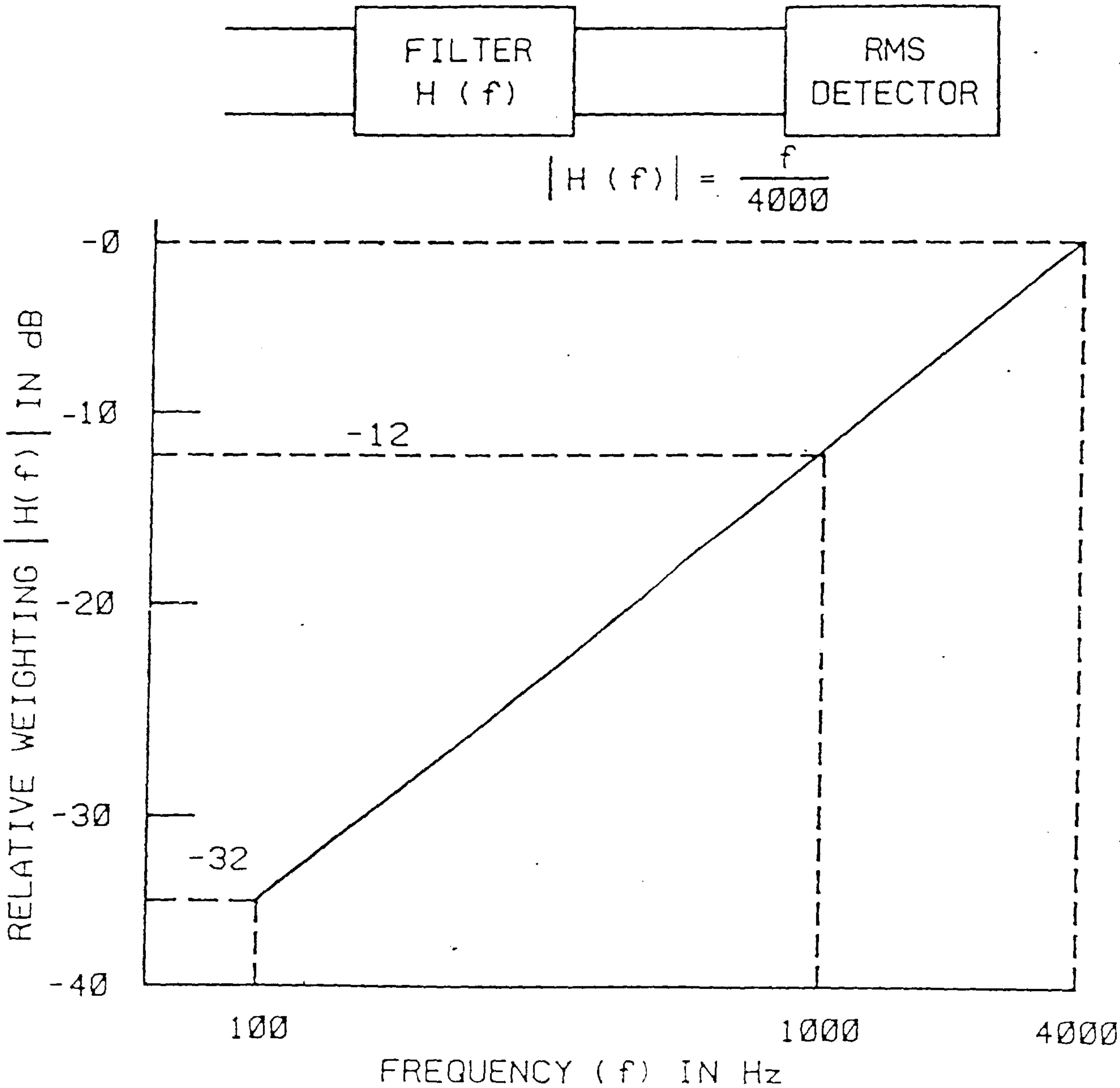


FIGURE 17 WEIGHTING FUNCTION RESPONSE

4.3 Baudot Code Operation

[Section 4.3 applies to all TDDs.]

All TDDs shall provide Baudot code operation employing half-duplex asynchronous transmission.

4.3.1 Frequencies

Baudot code operation shall use the following frequencies with both acoustic and direct coupling:

Signal	Frequency	Tolerance	
		Transmit	Receive
Mark	1400 Hz	$\pm1\%$	$\pm4\%$
Space	1800 Hz	$\pm1\%$	$\pm4\%$

4.3.2 Bit Duration

The bit duration shall be 22.00 $\pm$ 0.40 milliseconds to provide a nominal baud rate of 45.45 baud.

4.3.3 Character Format

4.3.3.1 Transmit

The Baudot code for each character shall be transmitted with the following format with the data bits assigned in accordance with Table 4.1 with a "1" in the binary representation transmitted as a mark and a "0" as a space:

Bit	Start	Data	Data	Data	Data	Data	Stop
Signal	Space	LSB	Bit 2	Bit 3	Bit 4	MSB	Mark
Number of bits	1	1	1	1	1	1	1.42-2.0 Required 1.42-1.5 Desirable

where LSB is the least significant bit and MSB the most significant bit.

The bits shall be transmitted from left to right.

4.3.3.2 Receive

The TDD shall be capable of receiving characters with the format of 4.3.3.1 with a stop bit at least 1.0 bit in length or longer. It shall be capable of receiving characters with the space tone of the start bit the first tone received or with a mark tone preceding the start bit.

4.3.4 Mark Hold Time

The mark tone of the stop bit shall be transmitted for a minimum of 150 milliseconds after the end of the last space data and a maximum of 300 milliseconds after the end of the stop bit if another character is not transmitted during this period.

TABLE 4.1

Minimum Set of Baudot Codes for TDD's

DEC	HEX	BINARY*	LETTER	FIGURE**
0	00	00000	NULL (BACKSPACE)	NULL (BACKSPACE)
1	01	00001	E	3
2	02	00010	LF***	LF***
3	03	00011	A	-
4	04	00100	SPACE	SPACE
5	05	00101	S	
6	06	00110	I	8
7	07	00111	U	7
8	08	01000	CR***	CR***
9	09	01001	D	$
10	0A	01010	R	4
11	0B	01011	J	
12	0C	01100	N	,
13	0D	01101	F	
14	0E	01110	C	:
15	0F	01111	K	(
16	10	10000	T	5
17	11	10001	Z	"
18	12	10010	L	)
19	13	10011	W	2
20	14	10100	H	
21	15	10101	Y	6
22	16	10110	P	0
23	17	10111	Q	1
24	18	11000	O	9
25	19	11001	B	?
26	1A	11010	G	
27	1B	11011	FIG****	FIG****
28	1C	11100	M	.
29	1D	11101	X	/
30	1E	11110	V	;
31	1F	11111	LTRS****	LTRS****

* Left most bit is the most significant bit

** These symbols should be used for all newly developed TDDs. Some existing TDDs may provide other symbols for some codes.

***<CR> and <LF> may be manually and/or automatically generated. If automatically generated, a sequence described in 4.3.5 is to be sent to allow adequate time for older electromechanical TDDs to respond.

****<FIGS> and <LTRS> may be generated by a single shift function.

4.3.4.1 Short Mark Hold Time

The receiver should be capable of receiving characters with a mark hold time of as short as 90 milliseconds after the end of the last space bit. This may result in the shortening of the last data bit and elimination of the stop bit or the shortening of the stop bit.

4.3.5 TTY Compatability

To improve compatibility with electromechanical teletypewriter machines, TDDs must transmit an automatic <CR> and <LF> at a maximum of 72 characters. An effort must be made to provide time for the carriage to return. A standard practice is to transmit a non-printable character to provide this time. It is desireable that TDDs transmit <CR><LF><LTRS> or <CR><LF><FIGS> after a maximum of 68 printable characters. (The choice of <LTRS> or <FIGS> depends upon whether letters of figures were being sent at the end of the last line.) It is also desireable that an attempt be made not to split transmitted words at the end of a line.

4.4 ASCII Operation

[Section 4.4 applies to all TDDs providing ASCII operation.]

ASCII operation employing full duplex transmission using the frequencies in 4.4.1.1 and 4.4.1.2 is a recommended option in addition to Baudot code operation. When ASCII operation is provided as an option, Baudot code operation shall be provided unless the user selects ASCII operation.

4.4.1 Frequencies

ASCII operation shall employ two pairs of frequencies, one at the TDD originating the call and one at the TDD answering the call. All TDDs shall provide both sets of frequencies. The TDD shall respond only to the receive frequencies for the originating or terminating TDD as appropriate to the call.

4.4.1.1 Originating Transmit - Terminating Receive

The originating TDD shall transmit the following frequencies which shall be the receive frequencies for the answering TDD.

Signal	Frequency	Tolerance	
		Transmit	Receive
Mark	1270 Hz	±1%	±3%
Space	1070 Hz	±1%	±3%

4.4.1.2 Answering Transmit - Originating Receive

The answering TDD shall transmit the following frequencies which shall be the received frequencies for the originating TDD.

Signal	Frequency	Tolerance Transmit	Tolerance Receive
Mark	2225 Hz	±1%	±3%
Space	2025 Hz	±1%	±3%

4.4.2 Bit Duration

The bit duration shall be 9.09 ± 0.09 milliseconds to provide a nominal baud rate of 110 baud. Some TDDs may also provide operation at 300 baud. The bit duration at 300 baud shall be 3.33±.03 milliseconds.

4.4.3 Character Format

The ASCII code for each character shall have the following format with the data bits assigned in accordance with Table 4.2 with a "1" in the binary representation transmitted as a mark and a "0" as a space:

Bit	Start	Data	Data	Data	Data	Data	Data	Data	Parity	Stop
Signal	Space	LSB	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	MSB	Bit	Mark
Number of Bits	1	1	1	1	1	1	1	1	1	2* 1**

*2 stop bits for 110 baud operation
**1 stop bit for 300 baud operation

where LSB is the least significant bit and MSB the most significant bit.

A mark signal shall be transmitted between characters.

4.4.3.1 Alternate Stop

It is desirable that TDD'S be capable of receiving characters employing a single stop bit.

4.4.4 Additional Characters

It is desirable that TDDs be capable of receiving lower case alphabetic characters. These are identical to the upper case alphabetic characters except for data bit 6 and the parity bit. These two bits are reversed. Displaying or printing the lower case characters as upper case is acceptable.

TABLE 4.2

Minimum Set of ASCII Codes for TDD's

DEC	HEX	BINARY*	CHAR
08	08	0001000	BS (Backspace)
10	0A	0001010	LF**
13	0D	0001101	CR**
32	20	0100000	SPACE
34	22	0100010	"
36	24	0100100	$
40	28	0101000	(
41	29	0101001	)
44	2C	0101100	,
45	2D	0101101	-
46	2E	0101110	.
47	2F	0101111	/
48	30	0110000	0
49	31	0110001	1
50	32	0110010	2
51	33	0110011	3
52	34	0110100	4
53	35	0110101	5
54	36	0110110	6
55	37	0110111	7
56	38	0111000	8
57	39	0111001	9
58	3A	0111010	:
59	3B	0111011	;
63	3F	0111111	?
65	41	1000001	A
66	42	1000010	B
67	43	1000011	C
68	44	1000100	D
69	45	1000101	E
70	46	1000110	F
71	47	1000111	G
72	48	1001000	H
73	49	1001001	I
74	4A	1001010	J
75	4B	1001011	K
76	4C	1001100	L
77	4D	1001101	M
78	4E	1001110	N
79	4F	1001111	O
80	50	1010000	P

TABLE 4.2 (Continued)

Minimum Set of ASCII Codes for TDD's

DEC	HEX	BINARY*	CHAR
81	51	1010001	Q
82	52	1010010	R
83	53	1010011	S
84	54	1010100	T
85	55	1010101	U
86	56	1010110	V
87	57	1010111	W
88	58	1011000	X
89	59	1011001	Y
90	5A	1011010	Z

* Most significant bit is left most bit.

** CR and LF may be manually and/or automatically generated.

5. APPLICATION NOTES

5.1 Ringer Equivalence Number (REN) Considerations

Several requirements related to the on-hook impedance of direct connected TDDs are dependent upon the Ringer Equivalence Number (REN). While the REN is derived from the ringer equivalence, it is actually a means of allocating the acceptable loading with respect to several parameters of all entities at the network interface.

REN can be any value from 0.0 to 5.0 in increments of 0.1. In addition, the sum of the REN's for all equipment entities which bridge a telephone line may not exceed 5.0 and therefore, if an equipment entity (e.g, a TDD, telephone, data set, etc.) has a REN of 5.0, it can be connected to the line only if there are no other entities (except those having a REN of 0.0) connected to that line. Entities having a REN of 4.0 or less can generally be connected to a line which has one telephone (telephones usually have a REN of 1.0) connected.

The limit of a particular impedance for a given REN is determined by dividing the nominal value of that impedance for a REN of 1.0 by the given REN. The limit of a particular current for a given REN is determined by multiplying the nominal value of that current for a REN of 1.0 by the given REN. Since rounding of the REN to the nearest 0.1 is required, the limiting value for a particular impedance or current for a given REN is actually determined by adding 0.05 to the given REN, then dividing or multiplying as required and rounding appropriately.

The REN of a TDD can be found by dividing the impedances and currents specified in this standard that are a function of the REN value by the actual impedances and currents of the TDD and taking the largest value. The use of impedances and currents that meet the requirements for all ringing types in this standard may result in larger REN values than required for compliance with the FCC Rules and Regulations in some cases.

5.2 Mark Hold Time

5.2.1 Function

The mark hold time provides a period of mark signal following the stop bits in Baudot operation when another character is not to be sent immediately. The purpose of this tone is to provide a means of echo suppression to prevent the transmitted signal from echoing back to the receiver of either of the two TDDs communicating with each other. If this echo suppression tone were not present, the receivers of TDDs could recognize the echos as valid data and garbled characters might result.

5.2.2 Receiver Modem Design

There are two different receiver modem design approaches in the TDD network for the Baudot code. The first, referred to as a single channel design, detects only the space signal. This design assumes that a mark signal is preesent at any time during the character interval following the receipt of a start bit when the space signal is absent and that no signal is present in the absence of a space signal at other times. The second design approach, referred to as a dual channel design, detects both the mark and space tones.

APPENDIX A BIBLIOGRAPHY

(A1) EIA Standard RS-470, Telephone Instruments with Loop Signaling for Voiceband Applications.

(A2) Federal Communications Commission Rules and Regulations, Part 68, Connection of Terminal Equipment to the Telephone Network.

(A3) ANSI X3.4-1977, American National Standard Code for Information Interchange.

(A4) ANSI/EIA 496-1984, Interface between Data Circuit-Terminating Equipment (DCE) and the Public Switched Telephone Network (PSTN).

(A5) IEEE Standard 269-1983, Method for Measuring Transmission Performance of Telephone Sets.

(A6) IEEE Standard 455-1976, Measuring Longitudinal Balance of Telephone Equipment Operating in the Voiceband.